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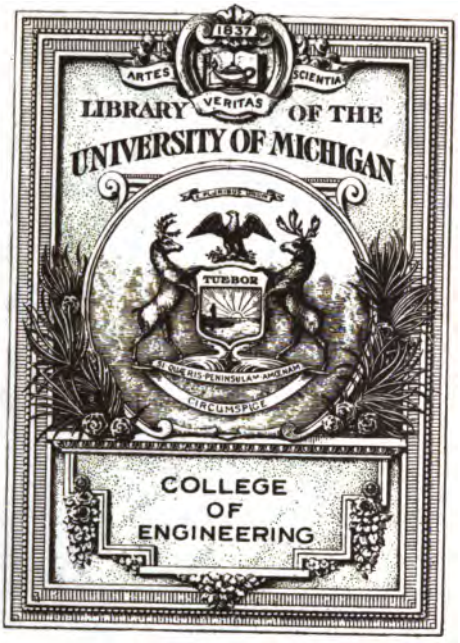
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Sanitary, Heating, *and* Ventilation Engineering

A General Reference Work

ON HYDRAULICS, MUNICIPAL WATER SUPPLY, DOMESTIC HOT WATER SUPPLY, HOUSE DRAINAGE AND VENTING, SANITATION METHODS, SEWAGE DISPOSAL SYSTEMS, HEATING AND VENTILATION, AND MANAGEMENT OF SANITARY ENGINEERING BUSINESS, INCLUDING MAKING ESTIMATES AND CONTRACTS

Prepared by a Corps of

SANITARY EXPERTS, CONSULTING ENGINEERS, AND SPECIALISTS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over One Thousand Engravings

FOUR VOLUMES

CHICAGO
AMERICAN TECHNICAL SOCIETY
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Grateful acknowledgment is here made also for the invaluable co-operation of the foremost Engineering Firms and Manufacturers in making these volumes thoroughly representative of the latest and best practice in every branch of the broad field of Heating, Plumbing, and Sanitation; also for the valuable drawings, data, suggestions, criticisms, and other courtesies.

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GATEWAY AND SIDE VIEW OF "RABBIT HOUSE" AT WYOMING, NEW JERSEY
Joy Wheeler Dow, Architect, Summit, New Jersey

WEBSTER FEED-WATER HEATER INSTALLED IN WEST JERSEY HOMEOPATHIC HOSPITAL. BEYOND THE FEED-WATER HEATER ARE BOILER-FEED PUMPS

Courtesy of Warren Webster and Company, Camden, New Jersey

Foreword

HISTORICAL records tell us that sanitation began with the civilization of man, and we find from Biblical records that Moses enunciated some forms of such, but never in the history of the world has so much attention been given to the sanitary conditions of municipalities as has characterized the past few years. Not a day passes but that brings to light new efforts on the part of the public officials and commercial enterprises of various kinds in behalf of public welfare.

¶ Every community and every individual with a semblance of progress is now engaged in one form or other of sanitary investigations and improvement. They realize that these professions are absolutely indispensable to civilization and now appreciate the untold value of pure air, pure water, the convenience and comfort of an adequate domestic hot water supply, modern sanitary fixtures, good drainage, sewerage, and sewage disposal, proper systems of steam, hot air, hot water and vapor heating, and speedy and efficient garbage collection and disposal.

¶ This is an age of new things. Present progress is just the beginning of what may be anticipated in these professions in the coming years. The enormous increase in population and the crowding together of masses of people on small areas have made our work very complex; so that whereas we used to speak of *Sewage Disposal*—which really means getting rid of the sewage—we are now concentrating our thoughts on *Sewage Purification.* The same statement applies to *Water Supply,* for a pure source can rarely be found these days, so we turn our attention to *Purified Water.* Again, the term *Garbage Disposal* interests us no longer, and we now do our utmost *to destroy* the garbage as quickly as possible without nuisance.

¶ Sanitary engineering can boast of wonderful scientific accomplishments and has rightly been termed "The Handmaid of Civilization." It enabled the Panama Canal to be built by eliminating yellow fever from the Canal Zone. It banished the deadliest enemy—Disease—in the European War, and lowered the death rate during the past sixty years by sixty per cent.

¶ All factory, office, and store managers now realize that there can be no efficiency in their stores or plants unless a perfect system of heating and ventilation is in existence. One of our largest mercantile concerns compiled statistics to ascertain the amount of money they were losing through colds contracted by their employes. It cost the firm twenty-five dollars every time one of their employes caught cold, and colds are brought about by inefficient ventilation.

¶ Another large concern in Baltimore rented a new and modern building which was looked upon as the acme of perfection. During the first two winters, twenty-seven per cent of the employes were ill. An efficiency expert was called in, who discovered defects in the heating and ventilation system. When these defects were rectified, the sickness fell to seven per cent, or a reduction of nearly four times.

¶ Notwithstanding the truly wonderful progress and splendid improvements made in these professions the past few years, there are countless and stupendous opportunities for us to do beneficial and noble work at this time.

¶ There are over twenty million buildings in the United States —millions of them with antiquated plumbing, and millions of others that have no plumbing whatever. Again, there are six-and-one-half millions of a type that should be radiator heated. Of the number already heated, ninety per cent are prospects for improvements in the efficiency of their heating plants.

¶ Quite recently a State Board of Health made a survey of the agricultural counties to ascertain the relation that prevails between health and farm sanitation, and they classed 206 farm houses sanitary, and 1068 unsanitary, and similar conditions exist in every rural district. However, the communities in these districts now realize that they can have in their homes all the modern sanitary appliances, which give them comfort and convenience previously undreamed of.

¶ In conclusion, let us say that all those entering upon or actually engaged in the sanitary, heating, and ventilation professions should realize the magnitude and importance of the work, their responsibilities to the community, and the necessity for continual study of these most important subjects.

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TRANSVERSE SECTIONAL VIEW OF COLONIAL MODEL HOUSE, SHOWING INSTALLATION OF HEATING PLANT.

BUSINESS MANAGEMENT

INTRODUCTION

Essential Qualifications. Practically all the large enterprises of today had insignificant beginnings. A few corporations have amassed colossal wealth. These successes have been shouted to the skies and have helped to encourage those about to engage in business on their own account.

Avoiding Failure. It should not be forgotten, however, that in all lines of endeavor only 5 per cent of our men are in business at the age of sixty on their own account, and that the bulk of our young business men fail in their initial year. Though it is deplorable, it must be admitted that the world is full of failures, and the bulk of failures in our own trade or profession may be attributed solely to the lack of knowledge of the fundamental principles upon which the proper conduct of the business depends.

Demands of Modern Business. The old-time methods and rule-of-thumb work will not stand the test today and, if you really desire success in this progressive age, you must snuff out the tallow candle and burn electric light. You must become a technical expert as well as a skilled mechanic in order to cope with the countless complex problems constantly arising in our scientific occupations.

Before venturing on the voyage of business, trim your sails with an abundance of technical knowledge, and see to it that you can design and install every branch of the work which may prove either beneficial or detrimental to the health of the community; otherwise your enterprise will be foolhardy and will come to inevitable wreck.

Business Education. A sound business education is an imperative and priceless possession and can be acquired only through close contact with business methods and business minds. In this respect your education will never be completed, if you think right, but will terminate only with your life. To your practical ability you must add a business and technical education, confidence,

integrity, whole-heartedness, energy, calm and quick judgment, and a general knowledge of human nature and the requirements of your community.

Effective Conversation. Another item of the greatest importance and one which is deplorably lacking among our present-day masters is the ability to converse effectively with their customers. Doubtless this is an art which does not come naturally to most men, yet it can and must be acquired. To say the right thing at the right time, in the right way and with the right result, will prove your greatest business puller.

Effective Stationery and Literature. The possession of this quality need not be confined to your own person, but can equally well be applied to your business stationery and literature. It will win you the respect of your customers and make them realize the benefits you are bestowing on mankind.

Up-To-Dateness. Another imperative trait you must possess is progressiveness, without which you cannot hope to rise above the mediocre class. It will bring you no reward to stick to the ways of your forefathers. They themselves were not content to fetter their activities by such a fallacy but lived up to the word *progress* by meeting the demands of altered conditions and new methods.

Progressive must be your middle name. Go after everything in our line which is new and, of course, true. Join associations and societies and exchange ideas. Respect your competitors and take an active part in the dissemination of business knowledge. Read the articles appearing in the trade and professional publications, which are a cheap clearing house and which furnish you with all the up-to-the-minute knowledge available.

Working Toward an Ideal. Finally, set up an ideal and forever aspire to it. Fill your tool bag with knowledge, character, service, thoroughness, enthusiasm, energy, and progressiveness, and you will assuredly win success and the respect of all men.

You may say that the qualifications enumerated above are too exacting; nevertheless, they are possessed by all the successful men conducting big businesses. Everything depends upon the man behind the business, and your business can be no bigger than you are; moreover, your heart must be stronger than your mind or you can never hope for success.

BUSINESS LOCATION

Assuming that the essential traits enumerated are in your possession, the next question to consider is the best place for you to open up a business.

Choice of Familiar or Strange Surroundings. Undoubtedly the city or town in which you have served your apprenticeship or worked for a number of years as a journeyman and made a large circle of useful friends is best, yet many prefer to leave their native town and strike out in a small town with a rapidly increasing population. The latter is an excellent idea for the young beginner, but expert advice should be obtained before making a rash move.

Help from Traveling Salesmen. The persons most capable of rendering you help in finding a location are the traveling salesmen from the large plumbing supply houses. They are constantly passing over their territory and can carefully note the growth of each town, the amount of business being done and likely to be done, the number of establishments already in existence, the class of work carried out, and details which may be specialized in, etc.

These gentlemen will gladly furnish you any particulars which may be helpful to you. In doing this, they make a friend of you and secure your patronage, thus being amply repaid for their advice.

Opportunities Advertised in Trade Journals. *Buying Out or Buying Into Established Businesses.* A perusal of the trade publications will provide you with apparently endless opportunities to secure a partnership in an established business, and businesses for sale will be cited in the special notice columns. The latter should be examined with great care for, generally speaking, a man rarely desires to dispose of a good paying business, nor does he wish to share his profits with a partner. The intending purchaser should look into every phase of the business very carefully before handing over the money.

An excellent plan in such cases is to join the firm as a journeyman and work in this capacity for six months, familiarizing yourself with the customers, local conditions, and the true value of the business.

Starting Your Own Business. All things considered, it is preferable to strike out entirely on your own hook, lay a solid foundation and build upon it.

Shop and Showroom. Having decided on the town you are to settle in, the place of business is the next move. Although not imperative, it is a decided advantage to have a showroom, with a workshop in the rear, and a very large and prominent, yet artistic, sign. The showroom need not be equipped with very high-priced articles at first; in fact, a goodly number of small inexpensive useful articles will not only make an attractive show but are likely to be turned to financial advantage.

The large cities have one great advantage over the smaller towns for business. In Chicago, for instance, there is no necessity for the young master to lay out his scanty capital in a large stock as he can obtain any article, in a few hours at the most, direct from the supply houses which are situated on all sides of him.

How to Become Known. How to become known in a strange town or to become better known in your own home town is an important point in your business development. That there are quantities of gold under the earth is true but it does not become a reality until it has been brought out of the mine. The same is true with your own business. You have prospective customers galore, yet these strangers or chance acquaintances must be converted into business clients who will order your services and goods and, consequently, increase your bank balance.

Starting Point. At the outset, visit a printer—one you would like for a customer—and order a supply of artistic letterheads, cards, estimate and contract forms, job tickets, books, etc. Take care to secure something which is superior to your competitors, for, if care is exercised in your commercial work, it makes people feel that your practical work will correspond with it. In Fig. 1 is shown an attractive toilet room which can be reduced and reproduced on the left-hand corner of your letterheads. A rather neat and unusual design for your business cards is shown in Fig. 2. However, it is not sufficient to have business cards printed, you must use them. Call on, and leave your card with, all the real estate agents, large property owners, and all those responsible for handing out work in connection with public institutions, etc.

Fig. 1. Well Arranged Modern Bathroom
Courtesy of J. L. Mott Iron Works, New York City

Another advisable course is to join the popular clubs and attend the social functions in your town. Meet and mingle with as many people as possible, remembering that you are not there for a good time only, but to extend your acquaintance and, indirectly, to secure business.

How to Keep Your Customers. It is not sufficient to secure customers; you must give satisfaction in order to hold them. Familiarize yourself with the requirements of your customers and serve them faithfully. Give them guaranteed goods at competitive

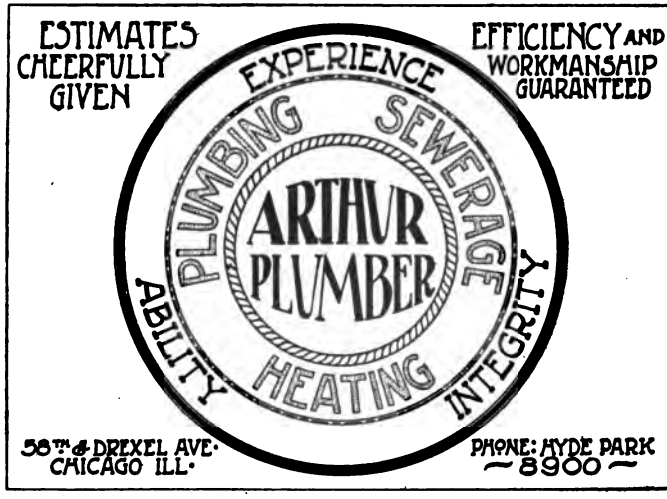


Fig. 2. Effective Business Card

prices, stand back of your guarantee, and let your word be as good as your bond. Keep your prices within reasonable bounds and give greater facilities to your customers than your competitors do. Further, be courteous and always insist that your customers are right, whether they are or not.

ADVERTISING

Value of Advertising. Doubtless your personal efforts, as just described, will find you many customers, especially in towns and smaller cities; if you wish to secure a big volume of business, however, advertising is imperative, for advertising is your silent salesman, bringing in business from remote places and from people with whom you never mingle.

Look at the hen; it lays an egg and cackles for ten minutes afterward. A duck never utters a sound after laying its egg. Result, thousands of hens' eggs sold to every duck's egg.

The chief forms of advertising of interest to you are newspaper advertising and direct mail advertising.

Newspaper Advertising. Consider first the advantages and the disadvantages of newspaper advertising. It has been rightly said that the newspaper is an organization for gossip, evolved by our civilization to meet the wants of the people. You most certainly gain wide publicity through the medium of the dailies, but your advertisement must be gossipy and newsy, and must appeal to the women as well as to the men readers.

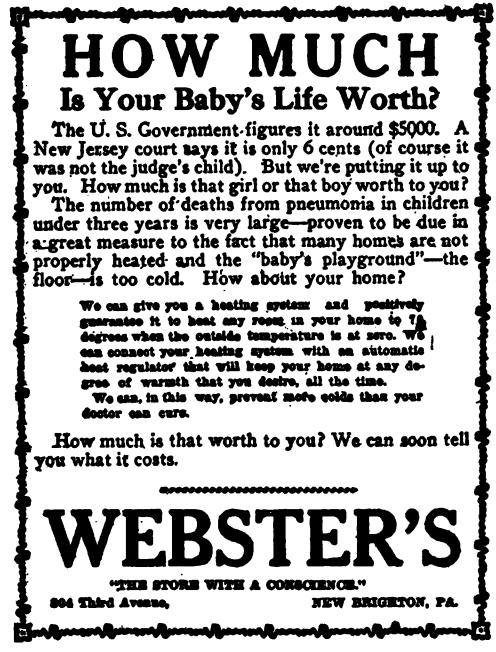

HOW MUCH
Is Your Baby's Life Worth?
The U. S. Government figures it around $5000. A New Jersey court says it is only 6 cents (of course it was not the judge's child). But we're putting it up to you. How much is that girl or that boy worth to you?
The number of deaths from pneumonia in children under three years is very large—proven to be due in a great measure to the fact that many homes are not properly heated and the "baby's playground"—the floor—is too cold. How about your home?
We can give you a heating system and positively guarantee it to heat any room in your home to 70 degrees when the outside temperature is at zero. We can connect your heating system with an automatic heat regulator that will keep your home at any degree of warmth that you desire, all the time.
We can, in this way, prevent more colds than your doctor can cure.
How much is that worth to you? We can soon tell you what it costs.
WEBSTER'S
"THE STORE WITH A CONSCIENCE."
804 Third Avenue, NEW BRIGHTON, PA.

Fig. 3. First Prize Advertising Set-Up

Characteristics of Good Copy. Should you prepare your own copy, keep in mind the following essential features:

(1) Will it attract attention?

(2) Is it snappy, true, and interesting?

(3) Does it supply a new want?

(4) Can the fixture advertised take the place of an old fixture and give better and cheaper service?

(5) Is it different from competing fixtures?

(6) Is it superior to every other?

Figs. 3 and 4 show excellent newspaper advertising set-up. They were awarded the first and second prizes in competition.

Method of Cheapening Space. Space in the daily and Sunday papers of a large city is very costly, but this can be cheapened

if a dozen or more masters incorporate on a general proposition and use large space. This idea was carried out with very excellent results in Milwaukee, Wisconsin, on the occasion of the Wisconsin Master Plumbers' Convention held there recently. Forty-five masters published their

THE CHILDREN

as well as the wife will enjoy the conveniences of the modern, sanitary bathroom. The daily bath will keep their bodies in a healthy condition and gives them added vigor to face the day's schoolwork and home duties. Your own efficiency will be increased through the morning bath.

Make this a modern Christmas by having a beautiful bathroom installed in your home.

F. W. RIEDEL

Plumbing—Heating—Lighting:

Bell 635 225 S. Park St. Auto 3283

Fig. 4. Second Prize Advertising Set-Up

business cards on a full page, while a strip down the center, Fig. 5, was effectively arranged to attract the attention of the public and make them realize the imperative need of good plumbing and sanitary engineering.

Indirect Advertising. Another form of newspaper publicity can be

THE MILWAUKEE JOURNAL

mbers

What We Stand For

The members of the Wisconsin State Association of Master Plumbers are organized for the purpose of promoting the science of sanitary plumbing. Their annual meetings are held for the purpose of discussing matters relating to plumbing and drainage.

Our objects are:

1. To improve sanitary conditions in city and rural communities.
2. To educate the public to a better appreciation of the services which the plumber renders in the interests of public health.
3. To co-operate with the state and local authorities in enforcing the state or local plumbing code in all its phases, knowing that such enforcement will tend to reduce the annual mortality rate in Wisconsin.
4. To co-operate with the state and local health boards in eliminating all disease-breeding conditions caused by improper disposal of sewage.

What Constitutes Sanitary Plumbing?

1. An efficient and safe system of water supply
2. The installation of an adequate and durable drainage system for the complete sanitary disposal of all wastes.
3. An equipment scientifically installed under the personal supervision of master plumbers, licensed locally or by the state, and tested by city or state plumbing inspectors. Thus the owner or occupant of the building will be protected against the indifferent or careless plumber

Plumbing and Its Relation to Health

1. Sanitary plumbing is of vital importance to every home, office and factory in the state of Wisconsin.
2. The doctor cures—the plumber prevents
3. Bad plumbing breeds disease—and hastens death
4. Plumbing and plumbers, therefore, are an important factor in safe-guarding the health of every community in this state.

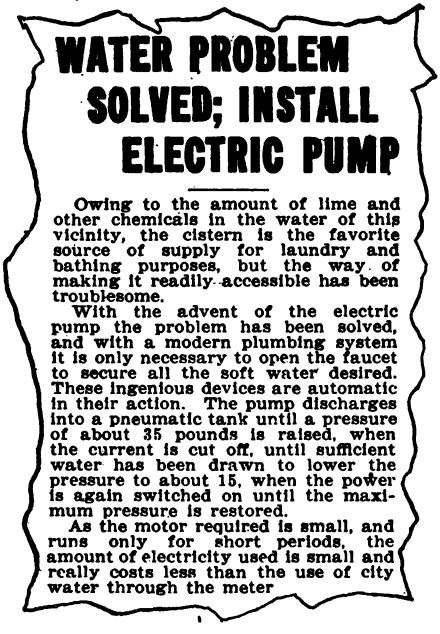
Suggestions to the Public

1. "Have confidence in your plumber," said Mayor Rading recently. The mayor is an honorary member of the association.
2. Do not let the so-called "handy man" do your plumbing. Call a competent plumber
3. Make your orders clear when telling your plumber what your troubles are. This will reduce costs by forestalling a trip back to the shop for tools and materials.
4. Avoid cheap work and cheap materials and fixtures. Good plumbing, like good clothes and good furniture, are more durable and satisfactory, and cost less in the long run.

Fig. 5. Illustration of Co-Operative Advertising

accomplished by general write-ups, two examples being shown in Figs. 6 and 7. Of course this benefits no particular individual but is most beneficial to the craft in general.

Direct Mail Advertising. By far the most effective mode of advertising for the profession is that known as direct mail advertising, for it secures many new customers—mostly for jobbing and alteration work in which no one will deny that there is profit. It possesses countless advantages over all other forms and allows you to assemble all desirable customers in one field and talk



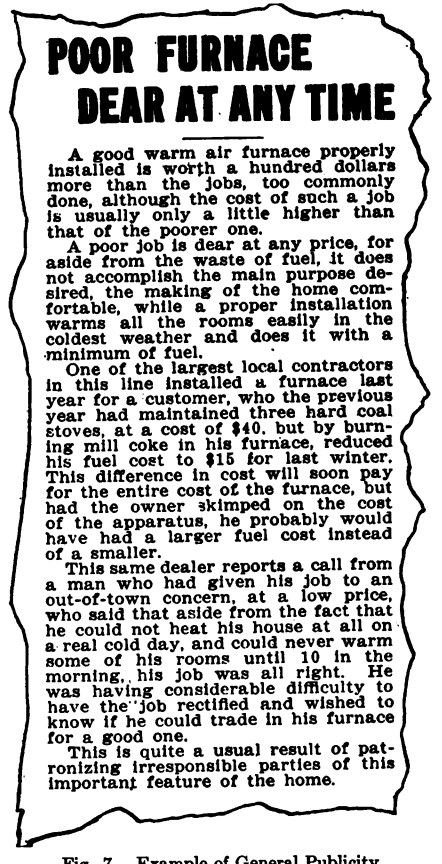
WATER PROBLEM SOLVED; INSTALL ELECTRIC PUMP

Owing to the amount of lime and other chemicals in the water of this vicinity, the cistern is the favorite source of supply for laundry and bathing purposes, but the way of making it readily accessible has been troublesome.

With the advent of the electric pump the problem has been solved, and with a modern plumbing system it is only necessary to open the faucet to secure all the soft water desired. These ingenious devices are automatic in their action. The pump discharges into a pneumatic tank until a pressure of about 35 pounds is raised, when the current is cut off, until sufficient water has been drawn to lower the pressure to about 15, when the power is again switched on until the maximum pressure is restored.

As the motor required is small, and runs only for short periods, the amount of electricity used is small and really costs less than the use of city water through the meter

Fig. 6. Example of General Publicity Advertising Which Pays



POOR FURNACE DEAR AT ANY TIME

A good warm air furnace properly installed is worth a hundred dollars more than the jobs, too commonly done, although the cost of such a job is usually only a little higher than that of the poorer one.

A poor job is dear at any price, for aside from the waste of fuel, it does not accomplish the main purpose desired, the making of the home comfortable, while a proper installation warms all the rooms easily in the coldest weather and does it with a minimum of fuel.

One of the largest local contractors in this line installed a furnace last year for a customer, who the previous year had maintained three hard coal stoves, at a cost of $40, but by burning mill coke in his furnace, reduced his fuel cost to $15 for last winter. This difference in cost will soon pay for the entire cost of the furnace, but had the owner skimped on the cost of the apparatus, he probably would have had a larger fuel cost instead of a smaller.

This same dealer reports a call from a man who had given his job to an out-of-town concern, at a low price, who said that aside from the fact that he could not heat his house at all on a real cold day, and could never warm some of his rooms until 10 in the morning, his job was all right. He was having considerable difficulty to have the job rectified and wished to know if he could trade in his furnace for a good one.

This is quite a usual result of patronizing irresponsible parties of this important feature of the home.

Fig. 7. Example of General Publicity Advertising

to them all at the same moment, with comparatively small cost and little time expended. Further, you can choose the opportune moment to offer a particular line of goods, illustrating these with enclosures in the form of booklets or folders, supplied gratis by the manufacturer. Return postal cards, Fig. 8, and order blanks, Fig. 9,

also will help to bring about speedy action and at a time when you most need the work.

Form Letters. The direct mail method is best carried out by a multigraphed or typewritten "form" letter which is designed to carry the message to a number of people in such a manner that it will receive the attention due a personal communication. The form letter may be sufficient for all your advertising needs and is the cheapest of all methods, for you are sure your letter reaches the person you want to interest. You can make a test of a small sec-

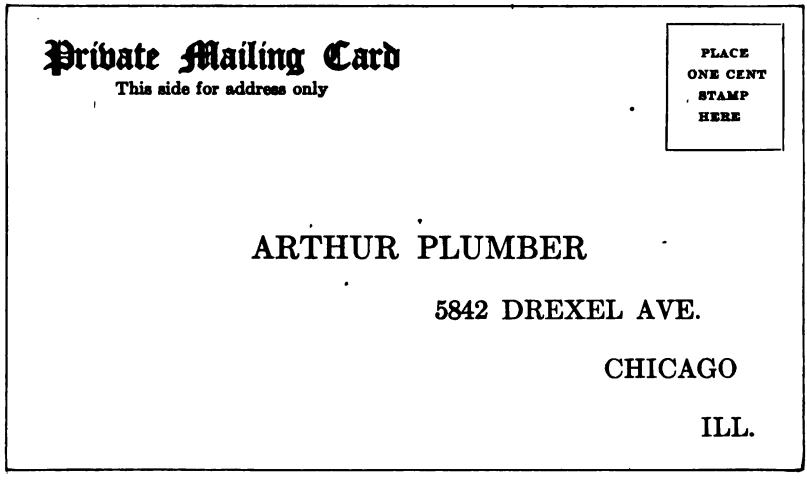


Fig. 8. Private Mailing Card

tion of the city as an experiment, circularizing the whole list if success attends your first efforts.

Mailing List. At the outset, a mailing list must be compiled and you must periodically revise it. Before compiling it, you must decide what classes or types of individuals are to be included in it. Only those who are desirable customers should be included in this list. You cannot sell bath rests to bachelors in a two-dollar per week rooming-house minus a bathtub, so study your list most carefully, and if your would-be customers are many in number, consult the city, trade, and telephone directories for first service.

The membership lists of clubs, societies, associations, etc., also will prove helpful, as will the society blue book, list of automobile owners, professional men, hotels, churches, select clubs, etc.

Again, the City Clerk's records are open to all reputable business men; and a list of property owners, tax payers, holders of building permits, saloon licenses, etc., may be compiled and may enlighten you considerably on your initial list taken from the directories.

ARTHUR PLUMBER
SANITARY AND HEATING ENGINEER
58th St. and Drexel Ave.

CHICAGO.....1917

NAME .....

ADDRESS.....

.....

Please call.....to

Repair water pipes.....

Clean water pipes.....

Repair toilet.....

Clean or repair range.....

Repair gas fixtures.....

Clean or repair heater.....

To estimate on.....

.....

Fig. 9. Order Blank

Now that rural sanitation has made such phenomenal progress, it will doubtless be advisable to secure a complete list of people in rural communities. Such a list may be secured from the rural mail carrier when he is off duty.

BUSINESS-PULLING LETTERS

Samples of Good Letters. And now for the composition of the letter, the most vital question of all. Letter writing to pro-

duce results is a very difficult matter, and the point is not what you want to say but what your readers want to hear. First, you must endeavor to attract attention; second, you must make your letter interesting enough to hold the reader's attention; and third, you must stimulate a desire to possess your goods and services.

The following is a letter for a beginner which can be multigraphed or typewritten. It must be signed by hand and should be sent in a sealed envelope with a two-cent stamp.

Dear Sir (or Madam):

Permit me to respectfully call your attention to the business I have opened recently at the above address.

Having had practical and successful experience in all branches of the work, I feel confident that I can give entire satisfaction. I use only high-grade material and this, coupled with skilled workmanship, is bound to show results. I hope you will trust me with your work.

Please give me a trial on something you are particular about and in a hurry for.

Very respectfully yours,

Here is a general letter which can be used at any time of the year and among all classes.

Dear Sir:

You have often felt like kicking your plumber for his tardiness in attending to your requirements.

My work and prices are right and service is my specialty, so kindly keep me in mind the next time you have a rush order.

You can put your hand on my latch-string by reaching your telephone. Hyde Park 8900 will bring immediate action.

Expectantly yours,

The following letter is suitable for Real Estate Agents and Managers of Property.

Dear Sir:

You can dispose of all your property if the sanitary conditions meet the approval of the fastidious housewives.

Why not let me figure on an up-to-date system of plumbing. Remember, my work costs no more than is equitable, and whether you desire to sell or to rent your property, modern plumbing will prove a profitable investment.

Call upon me to report on the sanitary conditions of your property. This will not obligate you in any way, and my report will be a valuable asset in your hands when your prospective purchaser calls.

Respectfully yours,

What might be termed a vacation letter is given below.

Dear Sir:

A line asking you to leave your keys with me when you go on your vacation.

This will be a most opportune time to put your plumbing and heating in good shape and, of course, you can depend upon me to do things right and to leave everything clean and ready for occupancy when you return.

Naturally, I assume all responsibility and guarantee satisfaction.

Respectfully yours,

Just as soon as the first frost sets in, circularize your entire list of customers and prospects with the following:

Dear Sir:

In case of fire call Main 0, but if you need a plumber, call Hyde Park 8900.

You never know at this time of the year at what moment the heater may give out or a water pipe may burst and work great havoc in the home, so I want to assure you of my immediate attention any hour of the day or night.

However, the wisest course is to have your plumbing and heating apparatus inspected now and thus obviate such an occurrence.

Please let me know if I shall look things over for you—remember this procedure will not obligate you in any way.

Expectantly yours,

A letter to the housewives just before spring cleaning begins will be timely and effective.

Dear Madam:

You are about to engage in a thorough house-cleaning and will doubtless spend money in beautifying your home.

Will you allow me to help you at this time by installing a beautiful porcelain sink without crevices, a sink which is easily kept clean, embodying the maximum of convenience, sanitary quality, and artistic beauty?

I can also eliminate the horrors of the wash day by installing laundry tubs which will abolish all stooping, lifting, and straining.

May I call and give you my expert advice without obligating you in any way?

Expectantly yours,

P.S.

Be sure to empty the foul water from your steam and hot water boiler and refill the system with fresh water. This month the flues also should be cleaned and sprayed with kerosene.

BOOKKEEPING

Books Required. Putting down on paper what you cannot carry in your head is the next detail to be considered, and although it is not imperative to commence with a very elaborate system of bookkeeping, it is advisable to begin with a cash book, sales book, purchase book, journal, ledger, trial-balance book, and order book, adding other books or methods to cope with any special phases of your business as they develop.

Inventory Record. The first step necessary in opening a new set of books is to make an inventory list of all assets and liabilities: cash; accounts receivable, or amounts owed by customers; accounts payable, or amounts due creditors; stock; and tools and fixtures on hand. The list of assets and liabilities should then be entered in the journal and posted from there to the ledger.

Cash Book. In the cash book is kept a record of all money received and paid out, the receipts on the left-hand side and the money paid out on the right-hand side. The cash book should be balanced every night.

Sales and Purchase Books. If you so wish, the sales book and the purchase book may be combined in the journal. Each day enter in the sales book copies of all the bills sent out to customers. At the end of the month gather together all your purchase bills and enter them in your purchase book or journal.

Posting in Ledger. From the sales book or journal the sales should be charged to the various accounts of the customers in the ledger. The total sales for the month should be credited to the sales account in the ledger. From the purchase book the purchases should be credited in the ledger to the accounts of the various supply houses. The total purchases for the month should be charged to the purchase account in the ledger.

A careful account of all expenses should be kept and charged to the expense account in the ledger.

Job Order Book. Orders for jobbing work can be given an order number in a job order book. They can be easily traced by numbering the jobs consecutively as they come in.

Job Ticket. It was the custom in the past to use weekly diaries in which the workmen entered up their time and the

material used on each job. At the end of the week these diaries were turned into the office so that the work could be charged up to the customer's account and the workmen's time could be made up in the pay-roll book.

Progress has eliminated this old method and, instead of a weekly diary, the workmen are given *combination price and job*

ORDER NO. 46 DATE Jan. 14, 17
LOCATION OF WORK 22 W. Erie Street
NATURE OF WORK Repair burst pipe
ORDERED BY Mrs. Jones ADDRESS 22 W. Erie Street
CHARGED TO George A. Kramer ADDRESS 542 E. Lake Street
PLUMBER Arthur Bateman PRICE $5.94

PERFORATED

ORDER NO. 46 **JOB TICKET** PAGE 46
DATE Jan. 14 17
OWNER George A. Kramer ADDRESS 542 E. Lake Street
TENANT Mrs. Jones ADDRESS 22 W. Erie Street
WORK TO BE DONE Repair burst pipe

DESCRIPTION OF WORK AND MATERIAL USED		
To repairing burst water pipe under ground in back yard		
2 Ft. 3/4" lead water pipe		64
2 Wiped plumbers' joints		60
EXPENSE Car fares		20
MECHANIC TIME DAY 3 hrs.	3	00
HELPER " " 3 hrs.	1	50
LABORER		
STATE OF JOB AT THIS DATE Completed		
SIGNED Arthur Bateman	5	94

Fig. 10. Typical Job Ticket

tickets, Fig. 10, for each job. These job tickets require the workmen to charge up daily all the time and material used on jobbing work.

As soon as the job is completed, the job ticket should be turned into the office; the price can then be extended and the bills

DAILY TIME SHEET

MECHANIC'S NAME Arthur Bateman & HELPER'S NAME Jack Junior

WORK DONE AT	DATE	FROM WHEN TO WHEN	No. OF HOURS	EXPENSE ITEMS	AMOUNT	DESCRIBE WORK
22 W. Erie St.	Feb. 12	8 to 11	3	Car Fare	20	Repairing burst pipe
176 Curtis St.	" "	11 to 12 30	1½			Cleaning grease trap
4 E. 5th St.	" "	1 30 to 5	3½	Car Fare	20	Fixing new range heater
16 Main St.	" "	5 to 5 30	(Double Time) 1			Knocking up burst pipe

Fig. 11. Daily Time Sheet

made out direct from the job tickets, saving the time and expense of entering the charges in the old-fashioned daybook.

Time Sheets. In some shops, in addition to the job tickets, the workmen are provided with daily time sheets, Fig. 11, on which they enter up the whole day's time, whether spent on jobbing or on contract work. The time sheets are turned into the office each night or the first thing in the morning, and the time on them is checked up with the time turned in on the job tickets.

No. _____

MATERIAL AND TOOLS TAKEN FROM SHOP

_____ 1917

FOR JOB _____

Printed on Yellow Paper

SIGNED

Fig. 12. Requisition Blank

Billing. It is now the custom to make out a bill and at the same time a carbon copy of the bill on the typewriter. All that is required is cheap paper and a carbon

paper. By this process you have an exact copy of the bill sent out, without the labor and expense of copying all the items by hand in the sales book. The original bills are mailed to the customer and the copies should be filed either by date or alphabetically in a loose-leaf binder.

Requisition Blank. To make sure that all material used is charged to the various jobs, there should be some method of recording what is taken out of the shop or stock room, as the workmen often fail to charge on their job tickets all the material used on the job.

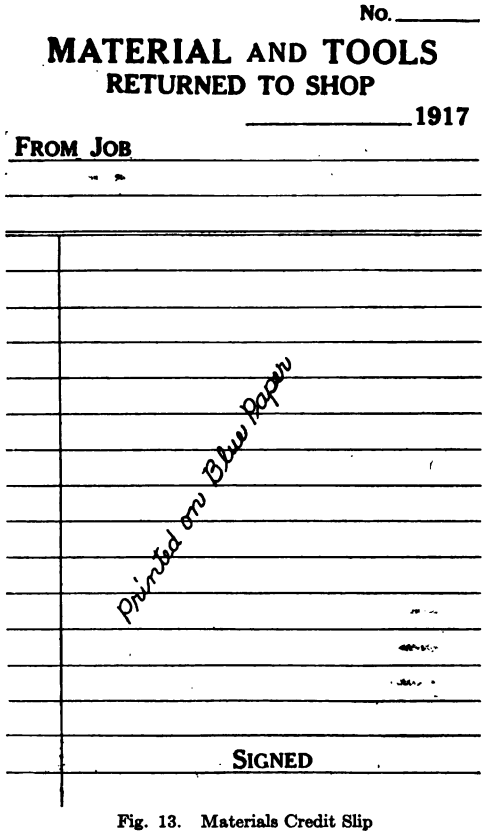


Fig. 13. Materials Credit Slip

When any material is taken from the shop, whether for jobbing or contract, a requisition blank, Fig. 12, should be filled in by the workman and given to the stock clerk or to the bookkeeper. It frequently happens that the quantity of materials required for a job cannot be exactly estimated beforehand and more material is often taken to a job than is actually used. In that case the material left over should be returned to the shop and a credit slip, Fig. 13, should be made out giving credit to the job for the material returned, and the credit slip should be turned over to the stock clerk or to the bookkeeper. The difference between what was taken out and what was returned unused will give the actual material used on a job and will govern the material charge against the customer.

Estimate No._____ Date_____

Estimate Forms. In addition to the financial books, an estimate book or loose-leaf printed estimate forms should be kept. Fig. 14 shows an excellent example which can be printed in either of the forms mentioned. This form was drawn up by a committee of the National Association of Master Plumbers for the benefit of its members and can be used on any plumbing job, large or small. The different items are arranged in divisions. In compiling the blank, the members of the committee aimed to list all the fittings so that a contractor, in making up an estimate, will not overlook any items.

In addition to a space for the cost of all fittings and labor, there are spaces in which incidental expenses, overhead expenses, and profit may be set down. A convenient size for the blank is 20 by 15 inches, and it is intended to be folded up for filing. There are notation and filing spaces on the back to be filled in so that when filed away it will be unnecessary to unfold the form in order to identify the estimate.

It will be seen that the estimate form begins at the sewer and water connections to the mains, and that it progresses in a logical manner through the roughing-in to the completion of the contract.

Another estimate form possessing merit is shown in Figs. 15 and 16. This form, arranged on the loose-leaf order, was devised and is being used with success by a prominent Chicago plumber.

Still another estimate form designed for a heating system is shown in Fig. 17.

Estimating. It is not our intention to deal with estimating here, yet it may not be out of place to offer a little advice on this stumbling block to profit-making, and we can advance no better arguments than those published by a joint committee of the National Association of Master Steam and Hot Water Fitters, and the National Association of Master Plumbers, and issued to their members in booklet form. They run as follows:

(1) Be sure that you do not attempt to estimate on work with which you are not entirely familiar.
(2) Confine your efforts to that class of work for which you have the necessary capital and the ability to handle properly.
(3) Be satisfied to creep before you attempt to run.
(4) Establish a reputation and a credit.
(5) Never sell anything below cost.

Archt. _____

Owner _____

Bldg. and Location _____ 191__

Quantity	Material and Labor	Dis	Total	Net
	Street Deposit by _____			
	Sewer permit by _____			
	Meter Box Cover_____ Brick_____ Cement_____ Lab_____			
◯	Ft. from Bldg. to Curb line_____			
	Ft._____" Sewerage to curb, Labor and material_____			
	Ft._____" Lead water sup. to curb, Labor and material_____			
	Ft._____" Lead water sup. from curb into_____			
◯	Ft. 6"_____' 4"_____' 9" Sewerage _____			
	6"_____ 4"_____ 9"_____ 6x6_____ 6x4_____ 9x6 Tees			
	6"_____ 4"_____ 9"_____ 6x6_____ 6x4_____ 9x6 Ys.			
	6"_____ 4"_____ 9" Ls.____ 6"_____ 4"_____ 9" Curves			
◯	4" P. traps_____ 4" Grates_____ B. W. Valve			
	Catch Basin_____ Gravel Basin			
	Gas Openings. (_____ Fuel_____ Lights)			
	ft. 2"_____' 4"_____' 6"_____ Ex. H. Soil Pipe			
	4x5".630_____ 2x4".310 Increaser_____ 4".560 C.O.Tee			
	2".65____ 4".130____ 6".325 Bends____ 2".100____ 4".260____ 6".650 T & Ys.			
	2x2".370____ 4x2".260 Tap T.____ 2".55____ 4".85 Rest			
	2".30____ 4".50____ 6".120 Screw Fer. Iron____ 5".125____ 4".80 Roof Plates			
◯	Lbs. Flashing____ Lbs. C. Lead____ Lbs. Oakum____ Gal. Gasoline			
	F. & W. Fittings			
	4"945.200____ 2"945.130____ 800.120____ 830.225____ 860.325____ 895.175			
	1070.225____ 1075.250____ 1105.325____ 1078.375____ 1095.175____ 905.225			
◯	1½"915.130____ 2"770.220____ H____ 4"740.475____ H____ 4"770.250____ H			
	4"720.840____ 2"950.300____ 2"825.35____ 2"1080.125____ 2"1050.300			
	2"1115.275____ 2"1095.150____ 2"700.375____ 1½"905.120____ 1½"950.300			
	4" Closet Bends_____ 4" Drum traps_____ 1½" Galv. Nips			
◯	2".85____ 1½".57 Ts.____ 2".85____ 1½".65 Ys.____ 2".65____ 1½".42 Ls			
	2".85____ 1½".42.45. Ls.____ 1½" St. Ls._____ Drge. Fit			
	Lb. Galv. Fit_____ C. I. Fit_____ Hangers_____ Lb. Strap			
	2"_____' 1½"_____' 1¼"_____' 1"_____" ¾"_____' ½"_____ G. I. P.			
	2"_____ 1½"_____ 1¼"_____ 1"_____ ¾"_____ ½"_____ Valves			
	¾" I. P._____ ⅝" L. P. C. & W._____" Sillcox_____ St. Washer_____			
	2"_____ 1½" Brs. Bush_____"_____"_____" Brs. Nipples_____			
	Amount Forward			

Fig. 15. Typical Estimate Form, Obverse Side

Qn'ty	Material and Labor	Total Net
	Amount Forward	
	2" 1½" Lead P traps ft Aq. Lead pipe	
	Lbs. R. M. Solder ft Str Lead pipe	
	Galv Nips Odd fittings Miscellaneous Sundries	
	" Tank Stand Furnace Connection Coil connection	
	" Smoke pipe Down spout Connection	
	" Refrigerator Drain Gas Heater connection	
	Days. Plumber D, Rough D, Finish) Time	
	Days Sewer builder Days Laborer	
	Liabilty Insurance Carfare and Sund Exp	
	Inspc Water 191 Final 19	

	Catalogue Number	Size	Plumbing Fixtures	Each Net
			Kit Sink "Faucet P trap	
			Bas Sink Faucet P trap	
			Bath Tubs Finish	
			Bath Tubs	
			Lavatories Faucet Trap	
			Lavatories Faucet Trap	
			Closet Tank Seat	
			Closet Tank Seat	
			Bas Closet Tank Seat	
			Part Laundry tray Cox	
			Gal Cap Heater, G Burner	
			Gal. Cap Tank Galv Boiler	
			Gas Heater, Shower	
			Seat Bath Urinals	
			Total Cost	
			Percentage and O. H. Expense	

Estimate to

Remarks

Fig. 16. Typical Estimate Form, Reverse Side

Estimate No.	**Architect**
Date	**Address**
Owner	**My Bid**
Location of Bldg.	**Lowest Bid**
Contract Awarded to	

WATER				STEAM			
QUAN.	ITEMS	PRICE		QUAN.	ITEMS	PRICE	
	Boiler No. Rated				Boiler No. Rated		
	Direct Radiation High				Direct Radiation		
	" "				" " High		
	" "				" "		
	" "				" "		
	" " Wall				" " Wall		
	Indirect Radiation				Indirect Radiation		
	Valves				Valves		
	"				"		
	Union Ells						
	" "				Automatic Air Valves		
	Air valves						
	No. Exp. Tank. Alt. Ga.						
	Thermometer				Valves on Mains		
	Valves on Mains				Pipe Fittings		
	Pipe Fittings				Boiler Covering		
	Boiler Covering				Pipe Covering		
	Pipe Covering				Bronzing Material		
	Bronzing Material				Smoke Pipe		
	Smoke Pipe				Valves for Dble. Boilers		
	Valves for Dbl. Boilers				Cold Air Ducts		
	Cold Air Ducts				Warm Air Ducts		
	Warm Air Ducts				Indirect Boxing		
	Indirect Boxing				Registers		
	Registers				Hngs. for Indirect Rads.		
	Hngs. for Indirect Rads.				Water Sup. & Blow-off		
	Overflow Pipe				Permits		
	Water Sup. & Blow-off				Freight and Cartage		
	Permits				Carfares & Incidentals		
	Freight and Cartage				Board		
	Carfares & Incidentals				Labor		
	Board						
	Labor						
	Total				Total		
	Profit				Profit		
	Amt. Bid				Amt. Bid		

Fig. 17. Estimate Form Particularly Adapted to Heating Work

(6) In estimating, remember that your bid should be made up of three principal divisions: materials and labor, overhead charges, and profit.
(7) Do not pay too great attention to what your competitor may be doing.
(8) Never be afraid to demand for a piece of work the price to which you feel sure you are entitled.
(9) Acquire the habit of refusing to take work at the other fellow's figure.
(10) Avoid doing work for general contractors.
(11) Be a loyal member of both your local and the national associations.

HOW TO MAKE A PROFIT

Estimating Costs. Remember when making up your estimate of cost, that there are three principal divisions of an estimate: *first,* the cost of all material and labor; *second,* the cost of doing business (overhead charges), which is rarely less than 15 per cent of the cost of the materials and labor; and *third,* the profit, which should never be less than 10 per cent. Anyone who willfully neglects the careful consideration of each of these three elements and fails to include enough to cover them need not wonder why he is making only a bare living.

Materials and Labor. Materials include all kinds, as taken from the plans and called for in the specifications, while the labor item includes the labor for properly installing the materials.

Overhead Charges. The division which, unfortunately, the majority of the craft lose sight of altogether, is what it costs you to do business (overhead charges) whether your business amounts to $5000 or $50,000 per year. It is an expense which you must meet and which you never will get back unless you charge it up. It is made up of such items as rent, insurance (both fire and labor), salaries of all employes (salemen, bookkeepers, stock clerks, and stenographers), interest, trucking, light, heat, water, telephone, taxes, car fares, bad accounts, waste material, labor lost, replacing defective goods, advertising, plumber's license, postage, printing and stationery, association dues, donations, etc., and is just as properly a part of your cost as boilers and radiators or bathtubs and soil pipe. Don't forget that you cannot afford to "throw it in".

Profit. Everyone of us is entitled to an amount over and above the cost, to provide a living for ourselves and those who are dependent upon us, and to compensate us for having had the

ability and the brains to get together an organization capable of doing the class of work which we are called upon to do. Everyone expects us to make this profit. Why disappoint them? It should never be less than 10 per cent over and above all other items of cost and it will be found safer never to figure less than 15 per cent. With these facts before you, if you fail to observe them, you do so willfully, and if you make a failure of your attempt at business, you have only yourself to blame.

Remember, "There are none so blind as those who will not see."

PROPER CALCULATIONS OF COSTS

Overhead a Troublesome Item. The majority of our masters endeavor to follow the above useful rules yet fail to make a profit no matter how much business they do. The reason for this is that, although they realize that their overhead expense is 25 per cent, they do not know how to add this amount to the cost of material and labor. This statement may sound ridiculous, nevertheless, there are not 40 per cent of the business men in all lines of endeavor who can add their overhead expense to the other costs and show the correct answer.

Calculating Overhead and Profit. About a year ago, the following question was asked in a number of business publications:

The wholesale cost of an article is $1.00; your overhead expense is 22 per cent; and you want 10 per cent profit. For how much must you sell the article?

This question was answered by 1000 executives in almost every line of business, yet 750 gave incorrect answers. The majority of them figured the problem this way:

Wholesale cost	$1.00
Overhead expense 22 per cent	.22
Profit 10 per cent	.10
	$1.32

This is wrong for, calculating the proper amount of overhead, there is no profit at all. A few figured it this way:

Cost and cash	$1.22
Profit at 10 per cent	.122
	$1.34

This also is wrong and the profit, instead of being 10 per cent, amounts practically to 1.4 per cent.

All the trouble is caused by adding the percentage to the wholesale, or cost, price instead of to the selling price. The correct solution is as follows:

	Per Cent	
Selling price	100	
Overhead expense	22	
Profit	10	
	32	
Wholesale cost	68	
Then 68 per cent is	$1.00	
1 per cent is	.0147	
100 per cent is	1.47	
		Ans. $1.47

Here is another practical example:

The invoice cost of a lavatory basin is $10.00. Your overhead expense amounts to 20 per cent. You want to make a profit of 20 per cent. At what price will you sell the lavatory?

	Per Cent	
Selling price	100	
Overhead expense	20	
Profit	20	40
		60
Then 60 per cent is	$10.00	
1 per cent is	.0166	
100 per cent is	16.66	
		Ans. $16.66

We will now prove this correct:

Selling price equals 100 per cent		$16.66
Cost of article	$10.00	
20 per cent of selling price, $16.66, equals overhead charges	3.33	
20 per cent of selling price, $16.66, equals profit	3.33	
	$16.66	

Rules to Remember

If your overhead charges amount to 10 per cent and you desire a profit of 10 per cent, divide the cost of the article by 80 and multiply by 100 to find the selling price.

If your overhead charges amount to 10 per cent and you desire a profit of 15 per cent, divide the cost of the article by 75 and multiply by 100 to find the selling price.

If your overhead charges amount to 15 per cent and you desire a profit of 15 per cent, divide the cost of the article by 70 and multiply by 100 to find the selling price.

If your overhead charges amount to 15 per cent and you desire a profit of 20 per cent, divide the cost of the article by 65 and multiply by 100 to find the selling price.

FORM OF SPECIFICATIONS AND CONTRACT

Desirability of Printed Forms. In submitting your bid to the customer, use the following form printed on your own letterheads. The adoption of this suggestion will add prestige to your business and obviate all disputes afterward. Furthermore, you will have the customer's agreement to pay for the work on a certain day.

CONTRACT FORM

We hereby submit specifications and bid for.....

.....

.....

.....

.....(half page left blank).....

.....

.....

We guarantee all material used in this contract to be first class and the entire job to be done in a neat and substantial manner. Any alteration or deviation from the plans herein agreed upon involving extra expense, labor, or material will be executed upon written orders for the same, and will become an extra charge over the sum mentioned in the contract.

We hereby propose to furnish and erect complete in accordance with the above specifications for the sum of,.....

.....Dollars ($.....)

Payments to be made as follows.....

.....

.....

Date.....Signed.....

The foregoing terms, specifications, and conditions are satisfactory, and the same are hereby accepted and agreed upon, and.....hereby authorize you to execute the same.

Signed.....

Date.....

This contract is void 30 days from date unless signed.

COLLECTIONS

Importance of Good Collection Methods. The last but by no means the least important part of your business to be considered is the collection of your outstanding accounts.

Every master has outstanding accounts and bad debts, the money from which he could use to advantage in conducting his business on more economical lines, but the young beginner is much more likely to suffer in this respect than the older master with a substantial balance or established credit at the bank.

You certainly must adopt an effective plan to collect your money when due, for you will find your employes demand their wages on Saturday noon, and the supply houses will allow you only 30 days credit.

Again, you are likely to secure exceedingly slow paying customers who have obtained all available credit from a competitor of yours and have come to you for no other reason.

In any case, collect your accounts when they become due, and remember that there is neither harm nor insult in asking a man for the money he owes you in exchange for your material and skilled services, and no man possessing integrity will feel offended if approached in the proper manner.

Diplomacy Necessary in Collections. Of course, all customers are not alike, but in every instance your money should be collected by persuasion rather than by force. Above all things, the good will of the customer must be retained in the process.

Money on the books is, in most part, like the bird in the bush—it needs catching not frightening away; and your collections must be made in a diplomatic manner. Some people are wealthy and usually prompt in their settlement. They simply need reminding that their accounts are overdue. Others have very moderate means and need coaxing to make prompt settlement, while a third class are the "I should worry" type and will not pay until threatened.

Collection Methods. How, then, can we best collect this money speedily and with slight expense? There are three methods:

(1) Make every person to whom you submit an estimate

sign the contract form previously mentioned; then collect the account in person when due.

(2) Send a personal typewritten letter, following it up every three or four weeks.

(3) Use a series of multigraphed form letters and send out every three or four weeks.

At the commencement of your business career, the personal typewritten letters will be preferable to the multigraphed letters, yet they can be classed as form letters.

Types of Collection Letters. Here are four letters which will help you to collect outstanding accounts.

The first letter should remind your debtor of the account and solicit an order at the same time.

Dear Sir:

Please find statement of your account which became due January 1st. We assume that you have overlooked this, and we shall greatly appreciate a prompt settlement.

The stock of sanitary fixtures which we carry to meet the demands of our customers was never more complete than it is today, and this is the opportune time to carefully consider the sanitary conditions in your home.

An order for our fixtures and services will be as welcome as your check.

Very truly yours,

The second letter should be centered on the question alone, and a reason should be shown why the demand should be met.

Dear Sir:

You have not replied to our letter of January 1st, in which we respectfully asked you to send us a check covering your overdue account.

Of course, we know you intend to pay this, but we have to pay cash for all our material and

our workmen demand their wages every Saturday noon. Consequently, we must have prompt settlement of our accounts or we cannot quote such low prices for our high-grade material and appliances.

Be good enough to accept this view of the matter and let us have your check by return mail. Our money is in your hands.

Very truly yours,

The account is now very much overdue and a strong letter demanding at least part payment and embracing a veiled threat should be sent.

Dear Sir:

You know that we dislike to see the names of our old customers removed from our books but we are vitally interested in the debit standing against your name and must insist upon immediate settlement of your account.

Your patronage is highly appreciated by us, otherwise we would have forced a settlement much earlier, but if you will send us part payment of your account we will still have patience and refrain from adopting harsh measures.

Won't you drop in and talk the matter over or mail us a check right away? Please do.

Expectantly yours,

If these three letters fail to bring a reply, little sympathy need be shown, and the final letter should take the form of a threat to recover in a legal way.

Dear Sir:

You have neither sent us your check covering your account nor given us any reason for not doing so.

We have been as patient and respectful as possible during this time, but we are now forced to turn the matter over to our attorney for collection.

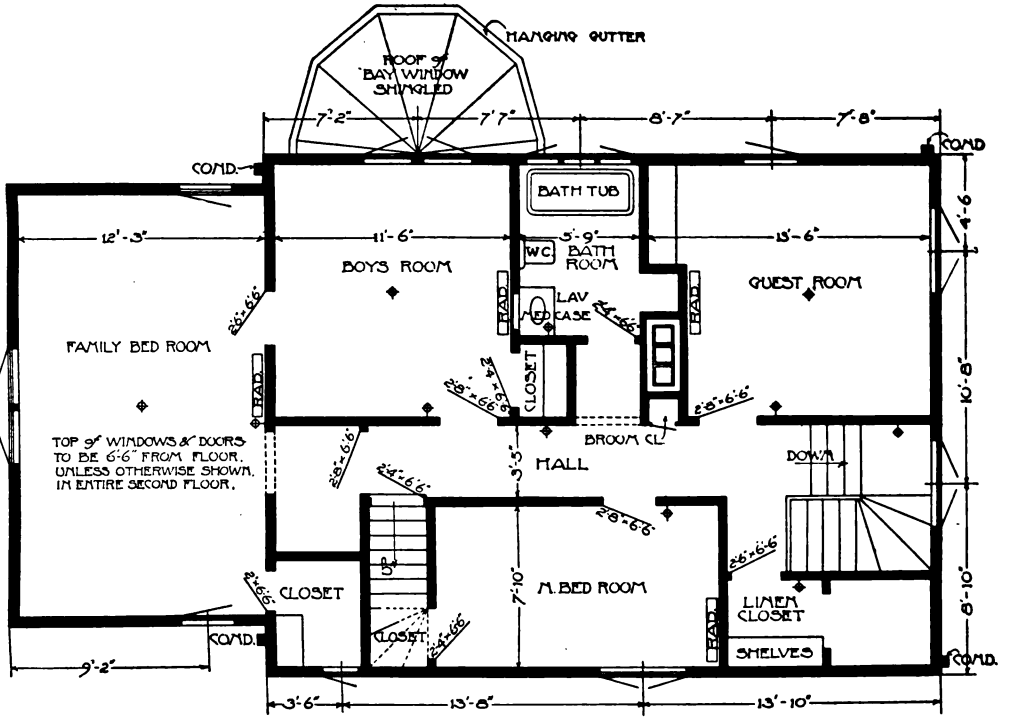
Needless to say, this procedure is distasteful to us and, for this reason, we are holding the matter in abeyance for another ten days.

Very truly yours,

_____

Cost of House—

Excavating	$ 25.00
Basement Wall and Cement Floor	75.00
Chimney and Brick Fireplace	120.00
Carpenter Work	1,650.00
Tinning	25.00
Plastering, Inside and Outside	175.00
Painting (without Glass)	125.00
Glass (Leaded Throughout)	67.00
Plumbing	221.00
Heating (Hot-Water)	250.00
Hardware, Special Designs, Strap Hinges on all Doors, Casement Window-Fasteners	116.00
Decorating	30.00
Windmill and Well	170.00
Chamberlain Weather Strips	61.00
Kewaunee Tank	100.00
Total	$3,210.00



SECOND FLOOR PLAN

HOUSE OF MR. MAX FERNEKES, AT BROOKDALE, WIS.

Fernekes & Cramer, Architects, Milwaukee, Wis.

ESTIMATING*

INTRODUCTION

The ability to estimate may be considered as the dividing line between the journeyman and the master builder for, no matter how skillful a mechanic may become, he can never "hang out his shingle" and invite patronage in his distinctive line of work unless he becomes able to make reliable estimates of material and labor to be furnished. To do this, something more than mere accuracy and quickness in figures or a mastery of mathematics is needed; the estimator must also have experience and judgment, an understanding of the more or less complicated details which go to make up a building, and a knowledge of current prices and discounts in the trade. It is the object of this text to point the way toward the acquirement of such of these essentials as may be imparted by words or figures, that is, to put in condensed form some of the common methods by which estimates are made up, and to point out some of the things which are to be avoided. Of course, the accuracy of judgment in estimating work is something which can be acquired only by experience.

As prices of labor and materials are constantly shifting with the times and with the location of the job, the figures quoted in this work must be taken only as proportionate, to be used in comparison with known quantities and methods, and not as a basis for making actual estimates. On account of the variableness in price, it is better, in general, to make estimates on the basis of days or hours of labor and of quantities of materials, so that they may be used for comparison in future work, and to this end all estimates should be carefully labeled and filed away for future reference. This should be done whether the bids were successful or otherwise; if a bid is successful, there will arise a good opportunity to compare the estimates of cost of the different items with the actual cost of execution; if a bid

*There is no such a thing as a universal or permanent standard price for anything. Prices vary in different localities at the same time and in the same locality at different times. The estimator must therefore acquaint himself with local market conditions in every case.

fails to win the job, satisfaction and experience may be gained by noting the items which may have been priced too high or too low. This data will be of great service in preparing future estimates, especially in the comparisons between estimated and actually executed work.

GENERAL FACTORS IN ESTIMATING

Use of Catalogues and Price Lists. Catalogues and price lists of all standard articles are easily obtained and should be kept at hand, properly indexed, for ready reference, as they contain a great deal of specific information. For close figuring, however, it will not do to rely upon these prices, as the amounts of trade discounts are not always included. These vary greatly from time to time, and often there are two or more discounts—a trade discount, a cash discount, and a variation in discounts made by different merchants—all of which the contractor must be familiar with to obtain bottom prices.

Data of this sort should be carefully tabulated for constant reference, in such a form that it may be easily revised and kept, so far as possible, up-to-date.

Time and Manner of Payment. The manner and time of payments is a matter to be considered in this connection, so that the contractor can take advantage of cash discounts, which often make a great difference in the cost of certain materials.

Determination of Profit. *Lump-Sum Method.* To the actual price of labor and materials must be added the profit and this will need careful consideration. A common method is to add a lump sum to the estimated cost of labor and materials, this amount varying with locality and customer, with the probable sharpness of competition, and with the circumstances of the contractor. This is a careless method, as it leaves no means for future comparison and no certain knowledge of just what the profits of a given job are.

Percentage Method. A better way is to base the profits upon a percentage of the estimated cost. This will vary, in ordinary cases, from 10 to 15 per cent. Ten per cent is the least that should be expected on any work, and is not enough for small contracts of two or three thousand dollars, but for large work, where there is a great duplication of parts and processes, it will generally prove sufficient.

Some contractors, whose workmen are required to perform especially skilful labor, figure 15 per cent on all labor and 10 per cent on materials.

Extent of Duplication of Parts. The matter of duplication is an important factor in estimating, as a considerable saving is often made if large quantities of material, either worked or unworked, are required; this is especially true of manufactured parts, such as bathtubs, sinks, traps, radiators, boilers, etc. Modern machines are capable of duplication with astonishing rapidity, and workmen can put together similar parts more quickly and cheaply than they can dissimilar members.

Transportation. The distance of the work from the shop of the contractor, or from centers of manufacture, will affect the cost to a marked degree, as much time is consumed in teaming and especially in handling the material a number of times.

If communication between the works and the building site can be established by water, it will usually save considerable expense in freight and handling, with perhaps less risk of damage, and, consequently, less expense for crating and boxing. A careful study should be made of the means of transportation to each different building site from the shop, the office, and the mill, and the data kept for future reference, subject to varying rates and conditions, to change of seasons, and amounts to be transported.

Special Conditions of Each Job. These are some of the more important matters which require preliminary consideration as affecting all estimates, but they are only a small part of the real question involved, as different localities and customs require different treatment, and numerous questions will arise to confront the contractor, all of which may be successfully met by the exercise of care and judgment.

METHODS OF ESTIMATING

Estimates are formed by many and varying methods, depending upon the degree of accuracy required, the capability of the contractor, and the character of the building. A broad division may be made between approximate estimates and accurate detailed estimates, only the latter of which should be considered when it is the intention actually to carry out the work under a definite contract.

Approximate Methods. *Estimating by Cubing.* Approximate estimates are obtained with varying degrees of accuracy by several methods, the most convenient and reliable of which is the system of cubing, i.e., the cubical content of the proposed building is ascertained and multiplied by a given price per cubic foot. This rate is obtained by careful comparison of the plans and requirements with similar buildings which have been erected under conditions as nearly as possible like the conditions under which the proposed building can be erected.

Several methods are used to determine the cubical units, depending upon the size and shape of the proposed building. One method is to multiply the square feet in the plan of the building by the distance from half the depth of foundations to half the height of the walls; another system uses the distance from the bottom of the foundation, and another obtains the actual cubical contents. Any of these may be used if the data for comparison is obtained in the same way, but all are subject to important variations which experience and judgment alone will determine. For instance, if the contour of the building is very uneven, with low portions, such as porches and sheds, and high portions, such as towers and cupolas, these must either be omitted from the whole and compared separately, or a lump sum added or subtracted according to the size and elaboration of these members.

Another variation arises in the size of rooms, giving a ratio of partitions and division walls which is not constant; then, too, a large building with many duplicated parts will, of course, require a different rating from a smaller one. The method of estimating by cubing is, therefore, at best approximate, and its degree of accuracy depends largely upon the experience and judgment of the contractor. Even long experience will afford no safeguard against unusual elaboration of interior or exterior, so that cube rates can be applied only to buildings of ordinary character, and comparisons are reliable only between buildings of like description and uses, as the treatment of even the same materials will vary largely in buildings of varying uses.

The height of the building will not increase the cube rate proportionately, unless the internal voids are alike, although it is certain that the higher the building is from the ground, the more time and

expense it requires to put the material in place, to say nothing of thicker walls and necessarily heavier construction.

Estimating by the Square. A convenient method of estimating is by the square of one hundred surface feet. This is especially applicable to office buildings, schools, mills, stables, and all buildings where the floors are few in number or similar in plan. For one-story buildings the price per square is taken to include the roof, walls, floor, and foundations, but for buildings of two or more stories the price per square should be taken separately for each floor, the lower floor being priced to include the foundations and the top floor to include the roof.

This method of estimating by the square is not so accurate as estimating by cubical contents, but the results are often more convenient and adaptable, because the tabulation of the square area of the various floors may be easily reduced to terms of accommodation for public buildings or shops. For instance, a given floor area in a school house means accommodation for a certain number of pupils; in a church, a certain number of sittings; in factories for the manufacture ofstaple goods, a certain number of machines and operatives.

Estimating by Units of Accommodation. This unit of accommodation is sometimes carried further, and, by the reverse process, made the basis of another method of estimating the approximate cost of such buildings as the above mentioned, i.e., schools, churches, factories, hospitals, etc. This is also a method by comparison, the known data being supplied by previous experience or calculation, and it is often valuable as a means of determining the approximate cost of buildings necessary to accommodate a given number of individuals or machines, before any definite plans have been drawn.

All of these methods are approximate, with varying degrees of accuracy, and should never be advanced as accurate, or used as the basis of a contract, unless the contractor has had a long and varied experience and feels absolutely certain of his judgment, or unless a proper margin is added for possible variations.

Accurate Method. *Estimating by Quantities.* The only sure and correct method of estimating is by taking off the actual quantities in detail and carrying out the prices accurately, with the cost of labor, the percentage for profit, and contingencies added.

For this, accurate and complete drawings and specifications are necessary to give the absolute quantity and quality of materials and

labor. The various items are then taken off, similar portions grouped, the amount of labor estimated, and a complete and classified schedule prepared and priced at current rates; the cost of transportation, board of men, and any other contingencies noted, a percentage of profit added, and a sum total reached which should be correct if faithfully done.

This, of course, takes considerable time, but is well worth the expense and trouble if a definite contract is to be made.

Preliminary Investigations. In order to estimate to a sufficient degree of accuracy, some things other than the possession of plans and specifications are necessary. A visit to the site should be made, to ascertain the nature of the soil, the levels of the lot, the distance from railroad or wharf, the condition of the roads, and the preparation of the site necessary to receive and dispose of materials. Some knowledge should be obtained of the nature of the subsoil, the presence of ledges or water below the surface which will require especial or costly treatment, etc. Often a deposit of sand will be found upon the site which will not only save carting away the material excavated, but, if of proper quality, may be used for the work. There are many such incidental factors involved, so that a knowledge of existing conditions will be of great advantage to the estimator.

Regarding underground conditions, there is always an element of chance, as the most thorough examination will not always reveal hidden perils. The author knows of a case where a mason had contracted for the building of a sewer, and was in a fair way to make a good profit, when a narrow vein of quicksand was uncovered, to overcome which not only took away all the anticipated profit but caused a severe loss besides.

Ground water is another source of loss and it will be well for the contractor to examine his contract closely, to see to what extent he is to furnish protection from this danger, as a vein of water which may have been temporarily stopped or diverted by the operation of building, will sometimes unexpectedly make its presence known during or after the completion of the work, when it may become a source of great annoyance and expense to the contractor if he has agreed to insure a waterproof job. Numerous illustrations could be given of the danger from unforeseen causes which can at best be only partially obviated by the most careful examination.

IMPORTANT ARITHMETICAL PRINCIPLES

In order to take off a building accurately, either by quantities, square, or cube, a good knowledge of arithmetic is necessary; and, while we may assume that the reader already possesses this, it may be well to include some of the essential rules of that branch of arithmetic which is known as mensuration. This consists primarily in the science of obtaining such definite data regarding given figures or surfaces, as area, solidity, capacity, linear dimensions, and comparison with other bodies.

Definitions of Arithmetical Terms. The *area*, or superficial dimension of any figure is the measure of its surface, without regard to its thickness or any other third dimension.

The *cubical content* of any figure is the measure of its solidity, or whole capacity, and has reference to the three dimensions, length, breadth, and thickness.

If the figure is considered as hollow, then the cubical content becomes its *capacity* or capability of containing matter.

The *linear dimension* of a figure is expressed by its length in a direct line in any direction and has no regard to breadth or thickness.

Units of Measurement. The application of these dimensions is made by fixing a unit by which the figure may be compared and the required dimension obtained: thus, for calculating the area of a figure the unit is usually a square, one side of which is the unit of length; and the area becomes the square measure of the figure.

This is expressed in common terms by square inch, square foot, square yard, or any other given unit, and the measure of the surface is computed by obtaining the number of these square units which are contained in the figure, the process being called squaring.

In a similar manner the cubical contents or solidity of a figure is obtained by computing the number of cubical units which it contains, which is called cubing it.

Rules for Determination of Unknown Dimensions. Numerous rules have been framed for obtaining unknown dimensions from given dimensions. There are given below the formulas and data which should enable the student to solve most of the ordinary problems which will arise in common practice.

Measurements of Surfaces

Linear Dimensions

Circumference of circle	= *diameter* × *3.1416*
Circumference of ellipse	= (*square root of one-half the sum of the squares of the two axes*) × *3.1416*
Radius of circle	= *circumference* × *0.159155*
Radius of circle	= *square root of area* × *0.56419*
Diameter of circle	= *circumference* × *0.31831*
Side of inscribed square	= *diameter* × *0.7071*
Side of inscribed square	= *circumference* × *0.2251*
Side of equal square	= *diameter* × *0.8862*

Area

Area of circle	= *square of radius* × *3.1416*
Area of circle	= *square of diameter* × *0.7854*
Area of circle	= *square of circumference* × *0.07958*
Area of circle	= ½ *circumference* × ½ *diameter*
Area of ellipse	= *product of both diameters* × *0.7854*
Area of triangle	= *base* × ½ *altitude* (*Fig. 1*)

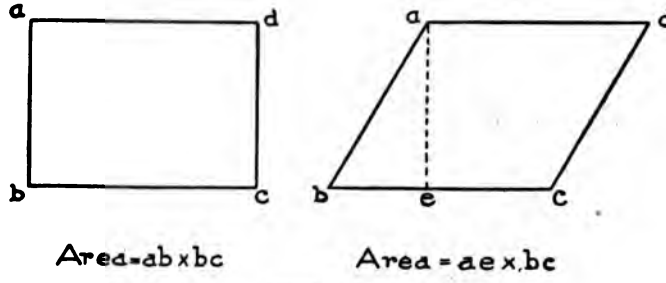


Fig. 1. Diagrams Illustrating Areas of Parallelograms

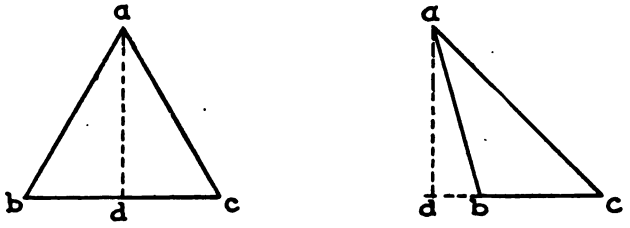
Area of parallelogram	= *length* × *breadth or perpendicular height* (*Fig. 2*)
Area of trapezoid	= *sum of parallel sides* × ½ *perpendicular distance between them* (*Fig. 3*)
Area of trapezium	= *sum of areas of triangles into which trapezium may be divided* (*Fig. 4*)
Area of regular polygon	= *length of one side* × ½ *perpendicular distance from center* × *No. of sides*
Area of irregular polygon	= *sum of areas of triangles into which polygon may be divided* (*Fig. 5*)

Area of ring included between circumferences of two concentric circles = *square of one diameter − square of other diameter) × 0.7854 (Fig. 6)*

Measurements of Solids

Linear Dimensions

Diameter of sphere . . . . . = *square root of surface × 0.56419*



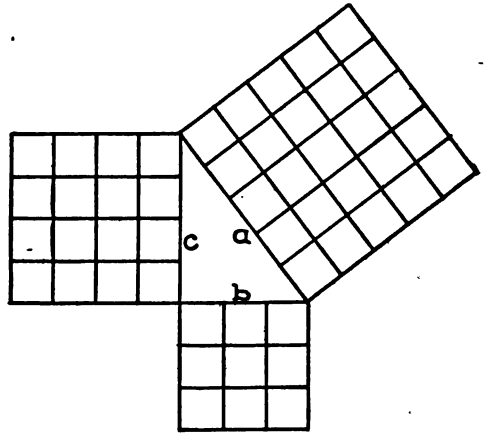
$$\text{Area} = bc \times \tfrac{1}{2} ad$$

Fig. 2. Diagrams Illustrating Areas of Triangles

Diameter of sphere . . . . . = *cube root of solidity × 1.2407*
Circumference of sphere . . . . . = *cube root of solidity × 3.8979*

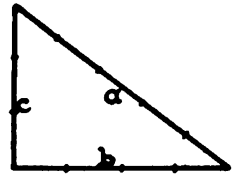
Area

Surface of sphere . . . . . = *circumference × diameter*
Surface of sphere . . . . . = *square of diameter × 3.1416*
Surface of sphere . . . . . = *square of circumference × 0.3183*



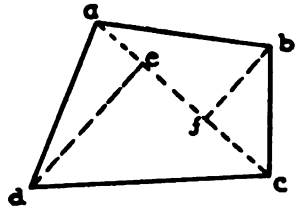
$$a = \sqrt{b^2 + c^2}$$

Fig. 3. Diagram Proof of Law of Right Triangle



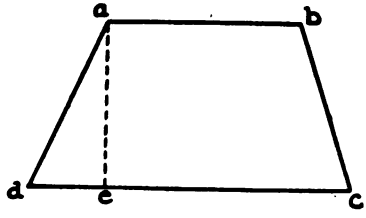
$$b=\sqrt{a^2-c^2}$$
$$c=\sqrt{a^2-b^2}$$

Fig. 4. Diagram of Right Triangle



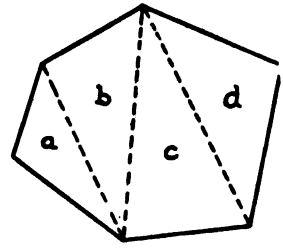
$$\text{Area}=\left(ac\times\tfrac{1}{2}bf\right)+\left(ac\times\tfrac{1}{2}de\right)$$

Fig. 5. Diagram for Finding Area of Trapezium



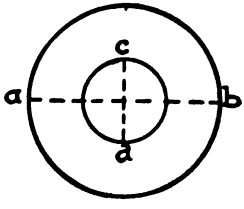
$$\text{Area}=\tfrac{1}{2}ae(ab+dc)$$

Fig. 6. Diagram for Finding Area of Trapezoid



$$\text{Area}=a+b+c+d$$

Fig. 7. Diagram for Finding Area of Irregular Polygon



$$\text{Area}=(ab)^2-(cd)^2\times.7854$$

Fig. 8. Diagram of Concentric Circles

Surface of cube . . . = *area of one side* × 6
Lateral surface of prism . . . . . = *perimeter of base* × *altitude*
Lateral surface of regular pyramid . . . = *perimeter of base* × ½ *slant height* (*Fig. 7*)
Lateral surface of frustrum of regular pyramid = *sum of perimeters of two ends* × ½ *slant height* (*Fig. 8*)

Solidity or Capacity

Solid contents of sphere . . . . . = *surface* × ⅙ *diameter*
Solid contents of sphere . . . . . = *cube of diameter* × *0.5236*

Solid contents of cone or pyramid . . . . . = *area of base* × ⅓ *altitude*
Solid contents of cylinder . . . . . = *area of base* × *height*

TABLE I

Areas of Circles

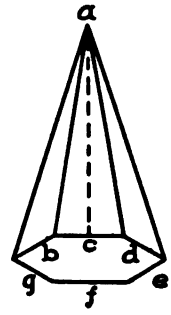
Diameter (in.)	Area (sq. in.)	Diameter (in.)	Area (sq. in.)	Diameter (in.)	Area (sq. in.)	Diameter (in.)	Area (sq. in.)
⅛	0.0123	10	78.54	30	706.86	65	3318.3
¼	0.0491	½	86.59	31	754.76	66	3421.2
⅜	0.1104	11	95.03	32	804.24	67	3525.6
½	0.1963	½	103.86	33	855.30	68	3631.6
⅝	0.3067	12	113.09	34	907.92	69	3739.2
¾	0.4417	½	122.71	35	962.11	70	3848.4
⅞	0.6013	13	132.73	36	1017.8	71	3959.2
1	0.7854	½	143.13	37	1075.2	72	4071.5
⅛	0.9940	14	153.93	38	1134.1	73	4185.3
¼	1.227	½	165.13	39	1194.5	74	4300.8
⅜	1.484	15	176.71	40	1256.6	75	4417.8
½	1.767	½	188.69	41	1320.2	76	4536.4
⅝	2.073	16	201.06	42	1385.4	77	4656.0
¾	2.405	½	213.82	43	1452.2	78	4778.3
⅞	2.761	17	226.98	44	1520.5	79	4901.6
2	3.141	½	240.52	45	1590.4	80	5026.5
¼	3.976	18	254.46	46	1661.9	81	5153.0
½	4.908	½	268.80	47	1734.9	82	5281.0
¾	5.939	19	283.52	48	1809.5	83	5410.6
3	7.068	½	298.64	49	1885.7	84	5541.7
¼	8.295	20	314.16	50	1963.5	85	5674.5
½	9.621	½	330.06	51	2042.8	86	5808.8
¾	11.044	21	346.36	52	2123.7	87	5944.6
4	12.566	½	363.05	53	2206.1	88	6082.1
½	15.904	22	380.13	54	2290.2	89	6221.1
5	19.635	½	397.60	55	2375.8	90	6361.7
½	23.758	23	415.47	56	2463.0	91	6503.8
6	28.274	½	433.73	57	2551.7	92	6647.6
½	33.183	24	452.39	58	2642.0	93	6792.9
7	38.484	½	471.43	59	2733.9	94	6939.7
½	44.178	25	490.87	60	2827.4	95	7088.2
8	50.265	26	530.93	61	2922.4	96	7238.2
½	56.745	27	572.55	62	3019.0	97	7389.8
9	63.617	28	615.75	63	3117.2	98	7542.9
½	70.882	29	660.52	64	3216.9	99	7697.7

For the convenience of the worker, there are tabulated in Table I the areas of circles with diameters varying from ⅛ inch to 99 inches.

The following rules are given for solving somewhat more complicated problems. The multipliers tabulated in Table II for the determination of measurements of polygons are the results of mathematical computations too elaborate to be repeated here.

It is also necessary at times to find an unknown dimension from one or more given dimensions. The following rules are given for the cases most commonly used by the estimator.

1. To find the hypothenuse of a right-angled triangle when the base and perpendicular are known:



$$\text{Lateral Area} = \tfrac{1}{2}\, ac \times (b+c+d+e+f+g)$$

Fig. 9. Diagram for Finding Lateral Area of Regular Pyramid

Add together the squares of the known sides and extract the square root of the sum (Fig. 9).

2. To find one side of a right-angled triangle when the hypothenuse and other side are known:

From the square of the hypothenuse subtract the square of the given side, and extract the square root of the remainder (Fig. 10).

3. To find the area of a regular polygon when the length of one side only is given:

Multiply the square of the side by the number opposite the polygon in Column A, Table II.

4. To find the radius of a circumscribing circle when the length of one side only is given:

Multiply the length of the side given by the number opposite the name of the polygon in Column B, Table II.

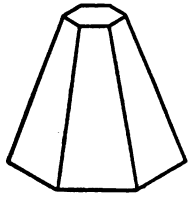


Fig. 10. Frustrum of Pyramid

5. To find the length of side of a polygon that is contained in a given circle, when the radius of the circle is known:

Multiply the radius of the circle by the number opposite the name of the polygon in Column C, Table II.

6. To find the radius of a circle that can be inscribed in a given polygon when the length of the side is given:

TABLE II

Table of Multiples to Compute Measurements of Regular Polygons, the Side of the Polygon Being Unity

Name of Polygon	No. of Sides	A Area	B Radius of Circumscribing Circle	C Length of the Side	D Radius of Inscribed Circle
Triangle	3	0.433013	0.5773	1.732	0.2887
Tetragon	4	1.	0.7071	1.4142	0.5
Pentagon	5	1.720477	0.8506	1.1756	0.6882
Hexagon	6	2.598076	1.	1.	0.866
Heptagon	7	3.633912	1.1524	0.8677	1.0383
Octagon	8	4.828427	1.3066	0.7653	1.2071
Nonagon	9	6.181824	1.4619	0.684	1.3737
Decagon	10	7.694209	1.618	0.618	1.5383
Undecagon	11	9.36564	1.7747	0.5634	1.7028
Dodecagon	12	11.196152	1.9319	0.5176	1.866

Multiply the length of a side by the number opposite the name of the polygon in Column D, Table II.

PRACTICAL ESTIMATING DATA

SCALE OF WAGES

The item of cost of labor, on construction of any kind, is at best a variable quantity, dependent to a large degree upon competition, demand, and labor organization.

The cost of labor is steadily on the increase, while the hours of labor are steadily decreasing. The tendency in both directions operates to lessen in a certain degree the effective power of labor, so that the amount of work done in a day does not represent what it did a few years ago.

The various schedules given below are based upon the current price of labor in 1916.

Wage Scale for Plumbing and Steamfitting Trades in Cities of the United States and Canada

(Figures given represent rate per hour)

City	Plumbers	Steamfitters	Helpers
Aberdeen, S. D.	$0.55	$0.50	$0.25
Albany, N. Y.	.75	.75	.05 to .25
Atlanta, Ga.	.50	.45	.16½
Baltimore, Md.	.50	.50	.28½

City	Plumbers	Steamfitters	Helpers
Birmingham, Ala.	$0.75	$0.75	$0.30
Boston, Mass.	.65	.62½	.31¼
Buffalo, N. Y.	.56¼	.56¼	.25
Burlington, Iowa	.50 to .55	.50 to .55	.25
Canton, Ohio	.53¼	.53¼	.10 to .30
Chicago, Ill.	.75	.75	.40
Cincinnati, Ohio	.62½	.62½	.35
Cleveland, Ohio	.68¾	.62½	.31¼
Columbus, Ohio	.56¼	.56¼	.25
Dallas, Texas	.75	.75	.31¼
Dayton, Ohio	.60	.60	.15 to .25
Denver, Col.	.62½	.62½	.21 to .31
Des Moines, Iowa	.62½	.62½	.25
Detroit, Mich.	.30 to .60	.30 to .60	.22 to .30
Duluth, Minn.	.62½	.60	.31¼
East St. Louis, Ill.	.75	.75	.42¾
Edmonton, Canada	.60	.60	.15 to .25
Evansville, Ind.	.50	.40 to .50	.35 to .50
Galveston, Texas	.62½	.62½	.31¼
Grand Rapids, Mich.	.50	.50	.30
Great Falls, Mont.	.87½	.87½	.43¾
Hartford, Conn.	.55	.55	.35
Indianapolis, Ind.	.62½	.62½	.31¼
Jackson, Miss.	.70	.50	.20
Jacksonville, Fla.	.50	.50	.25
Kansas City, Mo.	.68¾	.75	.37½
Lafayette, Ind.	.55	.55	.25
Logansport, Ind.	.70	.70	.25
Louisville, Ky.	.60	.55	.27½
Lowell, Mass.	.47½	.43¾	.31¼
Memphis, Tenn.	.62½	.62½	.33¼
Milwaukee, Wis.	.62½	.56¼	.28¼
Minneapolis, Minn.	.62½	.56¼	.28¼
Montreal, Canada	.40	.40	.20
New Orleans, La.	.56¼	.56¼	.25
New York, N. Y.	.68¾	.68¾	.37½
Oakland, Cal.	.62½	.62½	.43¾
Oklahoma, Okla.	.62½	.62½	.40
Omaha, Neb.	.68¾	.68¾	.28½
Oshkosh, Wis.	.50	.35 to .50	.25
Peoria, Ill.	.62½	.62½	.34½

City	Plumbers	Steamfitters	Helpers
Philadelphia, Pa.	$0.50	$0.50	$0.31¼
Pittsburgh, Pa.	.68½	.62½	.37½
Pittston, Pa.	.50	.50	.35
Portland, Ore.	.75	.75	.37½
Providence, R. I.	.60	.50	.30
Racine, Wis.	.65½	.65½	.31¼
Reading, Pa.	.47	.47	.25 to .30
Rochester, N. Y.	.59½	.59½	.43¾
Rock Island, Ill.	.63	.63	.20 to .25
Salt Lake City, Utah	.75	.75	.40
San Antonio, Tex.	.56¼	.56¼	.31¼
San Francisco, Cal.	.75	.75	.37½
Scranton, Pa.	.50	.50	.25
Seattle, Wash.	.75	.62½	.37½
Sioux City, Iowa	.60	.59¼	.45
Spokane, Wash.	.62½	.62½	.37½
St. Louis, Mo.	.75	.75	.32½
St. Paul, Minn.	.62½	.62½	.35
Toledo, Ohio.	.56¼	.56¼	.25
Toronto, Canada	.45	.45	.17
Troy, N. Y.	.50	.50	.25
Vancouver, B. C.	.50	.50	.30
Washington, D. C.	.56¼	.57½	.30
Wheeling, W. Va.	.56¼	.56¼	.35
Wilmington, Del.	.40	.40	.30

Wage Scale for Various Workers in the Building Trades in Boston, Massachusetts

(Figures given represent rate per day)

Trades	1916	Trades	1916
Carpenters	$4.56	Roofers	$4.80
Stone masons	5.20	Roofers' helpers	3.50
Brick masons	5.20	Steamfitters	5.00
Hod carriers	3.60	Steamfitters' helpers	2.50
Plasterers	5.60	Plumbers	5.20
Plasterers' helpers	2.80	Gasfitters	4.80
Lathers	5.20	Gasfitters' helpers	2.50
Quarrymen (9-hour day)	3.00	Electricians	5.00
Stone cutters	4.50	Painters	4.40
Tile setters	5.50	Iron workers	5.00
Cement finishers	5.00	Laborers	2.56

PRICES OF PERMITS, FIXTURES, AND INSTALLATION

A very wide range is possible in the selection and price of plumbing and heating fixtures and installation. For instance, in one house, a single bathroom fitted up to meet the fancies and purse of one man may cost more than the whole plumbing and heating outfit of his more modest neighbor. Nevertheless, it is a fact that the plumbing and heating of a house is a poor place to practice economy, as no part of the construction of a building needs more careful attention in execution or selection. A good job of plumbing costs about 10 per cent of the cost of the building, and of this outlay about 30 per cent represents the labor.

The following pages*, quoting the Chicago Masters' prices for all permits, fixtures, and fittings, will prove a most valuable help and guide for all those interested in the work. We suggest that you write the prices of your own locality beside these.

AMOUNT OF DEPOSIT REQUIRED BY CITY OF CHICAGO FOR PERMIT TO OPEN STREETS AND COST OF PAVING REPAIRS

	Minimum
For each opening in Creosoted Block Pavement	$50.00
For each opening in Asphalt Pavement	40.00
For each opening in Granite or Brick Pavement in reserve ..	40.00
For each opening in Granite or Brick Pavement out of reserve	30.00
For each opening in Macadam Pavement in reserve	15.00
For each opening in Macadam Pavement out of reserve .	20.00
For each opening in Cedar Block Pavement	10.00
For opening Cement Walk	10.00

(These are the net prices charged by the city)

Cedar Block Pavement—Deposit, $10.00.

Old block, 75 cents per yard.

New block, $1.00 per yard.

Asphalt Pavement—Deposit, $40.00.

Approximately $5.00 per yard for first yard and $3.00 for each additional or fraction of a yard in reserve. Minimum charge is usually $10.00. Out of reserve, $3.00 per yard or fraction.

Granite or Brick in Reserve—Deposit, $40.00.

Granite and Brick Out of Reserve—Deposit, $30.00.

*By courtesy of Mr. Peter M. Munn, Assistant Secretary, Chicago Master Plumbers' Association.

Approximately $5.00 for first yard and $2.00 for each additional or fraction of a yard on streets that are under reserve. When not under reserve, $3.00 per yard or fraction.

Macadam Pavement in Reserve—Deposit, $15.00.

Macadam Pavement Out of Reserve—Deposit, $20.00.

When under reserve, $5.00 for first yard and $1.00 for each additional or fraction of a yard. Out of reserve, $1.50 per yard. Minimum charge $5.00.

Brick. In reserve approximately $5.00 for first yard, $2.00 for each additional or fraction of a yard. Usual minimum charge of $10.00. Out of reserve $3.00 per yard.

In addition to above, $1.00 inspection fee is charged against each deposit.

DEPOSIT REQUIRED BY PARK COMMISSIONERS TO OPEN BOULEVARDS AND COST OF PAVING REPAIRS

South Park Board

Asphalt Pavement—Deposit, $100.00.

On Michigan Avenue, $5.00 for first yard and $3.50 for each additional yard. On Jackson Boulevard, $3.50 per yard.

Macadam Pavement—Deposit, $50.00.

Crushed stone, $1.65 per square foot. Labor on back filling, 21⅞ cents an hour. Other labor extra.

Water pipe opening in planting space between sidewalk and curb, deposit, $10.00. Where opening is made for both sewer and water in above space, a deposit of $25.00 is required.

West Park Board

Asphalt pavement, deposit, $20.00 and up, according to size of opening. $5.00 for first yard and $3.00 for each additional yard. Macadam pavement, minimum deposit, $25.00 and up, according to size of opening.

Openings for water pipe in narrow lot space inside curb, a deposit of $15.00 is required. Where there is a wide lot space, a deposit of $25.00 must be made. When refilling is done by the Board, a charge of 25 cents per hour is made for labor and 20 cents per yard for resodding.

Lincoln Park Board

Asphalt pavement, deposit, $20.00 to $100.00, according to condition of street. If the boulevard has been newly paved, a larger deposit is required. A charge of $2.00 is made for permits.

Macadam Pavement—Deposit, $20.00 to $50.00.

Openings for water pipe or sewer or both in planting space between sidewalk and curb, a deposit of $10.00 is required. Where openings are refilled or repaired by the Board, the work is done at net cost and deducted from the deposit.

AMOUNT OF DEPOSIT REQUIRED BY STREET CAR COMPANIES FOR PERMIT TO OPEN STREETS IN RAILWAY COMPANY RIGHT OF WAY

One track	$20.00
Center of tracks	30.00
Both tracks and center of tracks	50.00

Estimated cost is about 60 per cent of deposit

TAPPING WATER MAINS

City of Chicago

¾-inch tap	$ 5.00
1 -inch tap	10.00
1½-inch tap	15.00
2 -inch tap	20.00

STOP COCKS

Iron and Lead T and Lever—Handled. Check, Wastes, and Roundway

	Rough	Roundway
⅛-inch	$ 0.75	$ ....
¼-inch	.75	....
⅜-inch	.75	....
½-inch	1.25	....
⅝-inch	1.30	1.75
¾-inch	1.60	2.25
1 -inch	2.50	3.50
1¼-inch	4.00	5.75
1½-inch	6.50	9.00
2 -inch	11.31	16.00

VALVES

	Standard Globe and Gate	Jenk's Disc
½-inch brass	$1.50	$ 2.40
¾-inch brass	1.75	3.50
1 -inch brass	2.50	4.50
1¼-inch brass	3.50	5.50
1½-inch brass	4.75	8.00
2 -inch brass	7.00	13.00
2½-inch iron body	....	9.00
3 -inch iron body	....	12.00

	Standard Globe and Gate	Jenk's Disc
3½-inch iron body	....	$15.00
4 -inch iron body	....	19.00
5 -inch iron body	....	27.00
6 -inch iron body	....	38.10

CHECK VALVES

½-inch brass	$ 2.25
¾-inch brass	2.50
1 -inch brass	3.00
1¼-inch brass	4.00
1½-inch brass	5.00
2 -inch brass	7.00
2½-inch iron body	8.50
3 -inch iron body	9.00
3½-inch iron body	12.50
4 -inch iron body	15.00
5 -inch iron body	22.00
6 -inch iron body	30.00

RADIATOR VALVES AND UNION ELLS

	Valves	Ells
½-inch	$2.00	$1.25
¾-inch	2.75	1.50
1 -inch	3.50	1.75
1¼-inch	4.50	2.25
1½-inch	5.50	3.00
2 -inch	9.00	5.00

AIR VENTS

Automatic vent	$1.25
Key vent	.35

FLOOR AND CEILING PLATES

¾-inch iron N.P.	$0.25
1 -inch iron N.P.	.25
1¼-inch iron N.P.	.30
1½-inch iron N.P.	.35
2 -inch iron N.P.	.40

HEATING REPAIRS

Altitude gage	$6.00
Steam gage, 5-inch	6.00
Fusible plug	1.50
Thermometer	3.50
Gage glasses	.50

Pop safety valves, ¾-inch	$ 3.75
Pop safety valves, 1 -inch	4.50
Pop safety valves, 1¼-inch	5.50
Pop safety valves, 1½-inch	7.00
Pop safety valves, 2 -inch	10.00
Pop safety valves, 2½-inch	15.00
Steam cock, ½-inch	1.50
Square head, ¾-inch	2.00
Square head, 1-inch	2.75

SELF-CLOSING WORK

Self-closing work, sink bib	$3.50
Self-closing work, basin	4.00
Self-closing work, urinal	4.00
Self-closing work, flange and thimble	4.50
Self-closing basin, Mueller pattern	4.00
Self-closing basin, Gielow pattern	4.00

COMPRESSION AND FULLER COCKS

	Plain	N. P.
4½-inch bath cock	$....	$5.00
½-inch plain	1.25	1.50
½-inch hose	1.50	1.65
⅝-inch plain bibs	1.50	1.75
⅝-inch hose	1.75	2.00
⅝-inch hose, ¾-inch iron pipe	1.75	....
¾-inch hose	2.25	....
½-inch plain, F. & T. bibs	1.75	2.00
⅝-inch plain, F. & T. bibs	2.00	2.75
¾-inch plain, F. & T. bibs	2.50	2.75
½-inch hose, F. & T. bibs	1.75	2.00
⅝-inch hose, F. & T. bibs	2.00	....
¾-inch hose, F. & T. bibs	2.65	3.00
⅝-inch plain wash tray, F. & T. bibs	2.75	3.00
⅝-inch hose wash tray, F. & T. bibs	3.00	3.25

FULLER BIB REPAIRS

Fuller balls	$0.05
Fuller eccentric	.35
Fuller stem and ball	.40

BALL COCKS—COMPETITION

½-inch ball cock and ball	$3.00
⅝-inch ball cock and ball	3.25
¾-inch ball cock and ball	3.50

1 -inch ball cock and ball	$ 6.00
1¼-inch ball cock and ball	7.00
1½-inch ball cock and ball	10.00
2 -inch ball cock and ball	15.00

BALL COCKS—COMPOUND LEVER

½-inch ball cock and ball	$3.50
⅝-inch ball cock and ball	4.00
¾-inch ball cock and ball	4.50
5-inch ball	1.00
6-inch ball	1.30
8-inch ball	3.00
10-inch ball	6.00
12-inch ball	8.50

SILL COCKS

½-inch sill cocks	$2.00
¾-inch sill cocks	2.25

TRAP SCREWS

	1¼ in.	1½ in.	2 in.
Trap screws	$0.50	$0.60	$0.75

FERRULES

2-inch lead or brass ferrule	$0.75
4-inch lead or brass ferrule	1.25
2-inch I.B. clean out	.75
3-inch I.B. clean out	1.15
4-inch I.B. clean out	1.35
5-inch I.B. clean out	1.50
6-inch I.B. clean out	2.00
8-inch I.B. clean out	4.00
2-inch 45-degree brass ferrule	1.50
4-inch 45-degree brass ferrule	2.50

SOLDER NIPPLES AND BUSHINGS

⅜-inch straight solder nipples	$0.25
½-inch straight solder nipples	.40
¾-inch straight solder nipples	.45
1 -inch straight solder nipples	.50
1¼-inch straight solder nipples	.60
1½-inch straight solder nipples	.70
2 -inch straight solder nipples	1.00

SOLDER UNIONS

⅜-inch solder unions	$0.25
½-inch solder unions	.40
¾-inch solder unions	.45
1 -inch solder unions	.50
1¼-inch solder unions	.60
1½-inch solder unions	.75
2 -inch solder unions	1.25

WATER-BACK COUPLINGS

½-inch water-back coupling and spuds	$0.80
¾-inch water-back coupling and spuds	1.00
1 -inch water-back coupling and spuds	1.35

BOILER COUPLINGS

½-inch brass couplings	$1.25
¾-inch brass couplings	1.50
1 -inch brass couplings	1.75
¾-inch couplings, galvanized iron	.50
1 -inch couplings, galvanized iron	.75

STOP BOXES—IRON

5-foot Buffalo box	$2.00
5-foot extension pieces	1.00

STREET WASHERS

¾-inch street washer	$ 5.00
1 -inch street washer	8.00
¾-inch street washer, Murdock pattern	8.00
1 -inch street washer, Murdock pattern	10.00
Street washer keys	.15

IRON HYDRANTS

4-foot Murdock	$4.50
5-foot Murdock	5.00

ROD REPAIRS

Rod handles	$0.15
Rod rests	.15
Rod clamps	.15
Rod clamps, galvanized	.25

SOIL PIPE, CAST IRON

	Double	Single
2-inch "Extra Heavy," per foot	$0.45	$0.40
3-inch "Extra Heavy," per foot	.65	.60

	Double	Single
4-inch "Extra Heavy," per foot	$0.80	$0.75
5-inch "Evtra Heavy," per foot	1.05	1.00
6-inch "Extra Heavy," per foot	1.30	1.30
8-inch "Extra Heavy," per foot	2.30	2.25

CAST-IRON SOIL FITTINGS

Y or T Branches

	Calked	Tapped
2-inch	$0.80	$1.00
3-inch	1.00	1.25
4-inch	1.50	1.50
5-inch	2.25	....
6-inch	3.00	....
8-inch	8.00	....

Double Y or Sanitary T Branches

2-inch	$ 1.75
3-inch	2.25
4-inch	2.50
5-inch	6.50
6-inch	8.00
8-inch	12.50

SOIL BENDS—ALL ANGLES

2-inch	$0.80
3-inch	1.25
4-inch	1.50
5-inch	2.00
6-inch	3.50
8-inch	7.50

SOIL PIPE RESTS

2-inch	$0.50
3-inch	.75
4-inch	.75
5-inch	1.00
6-inch	1.25
8-inch	2.25

SOIL TRAPS—ALL ANGLES AND CLEANOUTS

2-inch	$ 5.00
3-inch	5.50
4-inch	6.00
6-inch	11.00
8-inch	15.00

IRON DRUM TRAPS

4-inch, regular	$3.00
4-inch, special	4.00

IRON CLOSET BENDS

4-inch, regular	$3.00
4-inch, special	4.00

REDUCERS

3/2	$0.45
4/2	.55
4/3	.75
5/3	.75
5/4	.75
6/2, 6/3, 6×4	1.00
8/2, 8/3, 8×4, 8×5, 8×6	4.00

INCREASERS

2/4	$1.75
4/5	3.00
4/6	3.50
5/7	6.00
6/8	7.00

BACK-WATER GATE VALVES

4-inch	$15.00
6-inch	20.00
8-inch	30.00

FLOOR DRAINS

Dehn's Acme	$4.50
Duffy	4.50
McCann	4.50

BELL TRAPS

	Iron	Brass
6×6	$1.50	$ 6.75
9×9	2.00	15.00
13×13	4.25	29.00

IRON BAR STRAINERS

4-inch	$0.30
5-inch	.35
6-inch	.40
7-inch	.50
8-inch	.65
9-inch	.80

IRON BASINS

Cast-iron blow-off basin, 24×30	$50.00
Cast-iron gravel basin, 24×30	55.00

GREASE TRAPS

Small size with water jacket	$30.00

DRAINAGE FITTINGS

90-Degree and 45-Degree L

1½-inch	$0.40
2 -inch	.50
2½-inch	.80
3 -inch	1.00
4 -inch	1.50
5 -inch	3.00
6 -inch	4.00
4 -inch drainage elbow, with 2-inch side outlet	2.50
1½-inch 3-way elbow	1.00
2 -inch 3-way elbow	1.50
3 -inch 3-way elbow	3.50
4 -inch 3-way elbow	6.00

90-Degree and 45-Degree Y

1½-inch	$0.75
2 -inch	.90
2½-inch	1.20
3 -inch	1.40
4 -inch	2.25
5 -inch	3.50
6 -inch	6.50

Double 90-Degree and 45-Degree Y

1½-inch	$1.00
2 -inch	1.25
2½-inch	2.00
3 -inch	2.50
4 -inch	3.50
5 -inch	6.50
6 -inch	9.50

GALVANIZED LONG SCREWS

1½-inch	$0.95
2 -inch	1.10
2½-inch	1.50
3 -inch	2.50

BLACK WROUGHT-IRON PIPE AND FITTINGS

	Pipe	Fittings
⅛-inch, per foot	$0.07	$0.08
¼-inch, per foot	.07	.08
⅜-inch, per foot	.07	.08
½-inch, per foot	.09	.10
¾-inch, per foot	.12	.15
1 -inch, per foot	.15	.22
1¼-inch, per foot	.20	.31
1½-inch, per foot	.25	.45
2 -inch, per foot	.35	.70
2½-inch, per foot	.52	1.08
3 -inch, per foot	.70	2.18
3½-inch, per foot	.90	2.82
4 -inch, per foot	1.10	4.00
5 -inch, per foot	1.50	5.25
6 -inch, per foot	2.00	6.50

GALVANIZED WROUGHT-IRON PIPE AND FITTINGS

	Pipe	Fittings
⅛-inch, per foot	$0.10	$0.14
¼-inch, per foot	.10	.14
⅜-inch, per foot	.10	.14
½-inch, per foot	.12	.17
¾-inch, per foot	.15	.22
1 -inch, per foot	.20	.35
1¼-inch, per foot	.28	.43
1½-inch, per foot	.32	.75
2 -inch, per foot	.45	1.20
2½-inch, per foot	.70	1.70
3 -inch, per foot	.90	3.25
3½-inch, per foot	1.15	4.25
4 -inch, per foot	1.35	6.00
5 -inch, per foot	1.85	7.00
6 -inch, per foot	2.50	9.50

NIPPLES

Black and galvanized nipples to be charged at price of foot of pipe.

Right and Left Nipples and Couplings

	Black	Galvanized
⅜-inch	$0.15	$0.20
½-inch	.20	.25
¾-inch	.25	.30

	Black	Galvanized
1 -inch	$0.30	$0.40
1¼-inch	.40	.55
1½-inch	.55	.75
2 -inch	.75	.95

UNIONS

	Black	Galvanized
⅛, ¼, ⅜-inch	$0.15	$0.20
½-inch	.20	.25
¾-inch	.25	.30
1 -inch	.30	.35
1¼-inch	.35	.45
1½-inch	.45	.65
2 -inch	.60	.85
1½-inch flanged union and gasket	1.40	2.75
2 -inch flanged union and gasket	1.65	3.25
2½-inch flanged union and gasket	2.00	4.00
3 -inch flanged union and gasket	2.50	4.75
3½-inch flanged union and gasket	3.00	5.75
4 -inch flanged union and gasket	3.25	6.50
5 -inch flanged union and gasket	3.50	8.75
6 -inch flanged union and gasket	5.00	10.00

TINNED—STRAPS

Up to 1 inch, each	$0.05
Over 1 inch, each	.10

PIPE HOOKS

Up to 1 inch, each	$0.05
1¼ to 2 inches, each	.10
3 and 4 inches, each	.15
5 inches, each	.20
6 inches, each	.25

PIPE HANGERS

	Black	Galvanized
⅜-inch	$0.25	$0.35
½-inch	.25	.35
¾-inch	.25	.35
1 -inch	.35	.45
1¼-inch	.35	.45
1½-inch	.35	.45
2 -inch	.35	.45

Band iron hangers same price as pipe hangers
Band iron, per foot, 25 cents

LEAD PIPE

Lead pipe and sheet lead to be billed by the pound at the rate of 18 cents per pound.

Strong	Lb. per Foot	Waste	Lb. per Foot
½-inch	2	1¼-inch	2
⅝-inch	2½	1½-inch	3
¾-inch	3	2 -inch	3½
1 -inch	4	3 -inch	4
1¼-inch	5	4 -inch	5
1½-inch	6	5 -inch	8½
2 -inch	8	6 -inch	10
2½-inch	11		
3 -inch	12		
4 -inch	16		

LEAD TACKS

Lead tacks, per pair	$0.25

SOLDER JOINTS

½, ⅝, ¾-inch	$0.40
1, 1¼-inch	.50
1½, 2-inch	.60
4-inch	1.50
Solder, per pound	.35

CALKED JOINTS

2-inch	$0.30
3-inch	.35
4-inch	.40
5-inch	.60
6-inch	.95
8-inch	1.75

BOILERS

		Stand
30-gallon, galvanized	$15.00	$1.25
40-gallon, galvanized	20.00	1.40
52-gallon, galvanized	30.00	1.85
63-gallon, galvanized	35.00	2.00
66-gallon, galvanized	45.00	2.00
82-gallon, galvanized	52.00	2.25
100-gallon, galvanized	75.00	3.00
120-gallon, galvanized	85.00	3.50
Boiler tap plugs	.....	.50

"ECONOMY" AUTOMATIC COMBINATION BOILER AND GAS WATER HEATER

(With Thermo-Valve Control)

18-gallon, 3×12	$ 40.00
24-gallon, 4×12	40.00
30-gallon, 5×12	40.00
40-gallon, 5×14	48.00
52-gallon, 5×16	60.00
66-gallon, 5×18	72.00
82-gallon, 5×20	80.00
100-gallon, 5×22	98.00
120-gallon, 5×24	116.00

Stands extra

"ECONOMY" REGULAR COMBINATION BOILER AND GAS WATER HEATER

18-gallon, 3×12	$24.00
24-gallon, 4×12	24.00
30-gallon, 5×12	24.00
40-gallon, 5×14	32.00
52-gallon, 5×16	44.00
66-gallon, 5×18	56.00
82-gallon, 5×20	64.00
100-gallon, 5×22	82.00
120-gallon, 5×24	90.00

Stands extra

BLACK STEEL TANKS

66-gallon	$60.00
85-gallon	63.00
100-gallon	65.00

Steam coils for above boilers, add $35.00

120-gallon	$70.00
140-gallon	75.00
150-gallon	78.00
180-gallon	84.00

STEAM COILS—GALVANIZED

66	$30.00
85	33.00
100	36.00
120	39.00
150	42.00
180	45.00

TANK HEATERS—CAST IRON—STEEL

140-gallon, self-feed, 16×30	$57.50
150-gallon, self-feed, 16×36	60.00
180-gallon, self-feed, 20×36	72.00

LEAD TRAPS

1¼-inch lead P or S traps	$1.25
1½-inch lead P or S traps	1.50
2 -inch lead P or S traps	2.00
4 -inch lead P or S traps	4.50
4 -inch lead drum traps, plain cover	4.00
4 -inch lead drum traps, N.P. flange cover	4.00
Bower traps, 1¼ inch	3.00
Bower traps, 1½ inch	3.50

LEAD BENDS

2-inch lead bends	$1.25
3-inch lead bends	2.00
4-inch lead bends	3.00

BOWER TRAP BOTTOMS

1¼-inch glass bottoms	$0.50
1½-inch glass bottoms	.35
1¼-inch lead bottoms	.50
1½-inch lead bottoms	.75
1¼-inch brass bottoms	1.25
1½-inch brass bottoms	1.75
1¼-inch rubber balls	.20
1½-inch rubber balls	.25
Gaskets for bower traps	.15

BRASS TRAPS

1¼-inch P and S traps, cast brass	$4.00
1½-inch P and S traps, cast brass	4.50
2 -inch P and S traps, cast brass	9.00
1¼-inch P and S traps, Competition	3.00
1½-inch P and S traps, Competition	3.50
2 -inch P and S traps, Competition	5.00

MURIATIC ACID

Per quart	$0.50

RUBBER GOODS

	Comp.	Special
Fuller balls, ⅜, ½, ⅝-inch	$0.05	$0.10
Fuller balls, ¾, 1-inch	.10	.15
Ideal basin washer		.25
Ideal bath washer		.35
Tank plunger washer, 1¼-inch		.25
Tank plunger washer, 1½-inch		.30
Tank plunger washer, siphon jet tank		.50
Slip joint washers, all sizes		.15
Douglas ball for high tank		.75
Douglas ball for low tank		1.00
Douglas special ball for low tank		1.25
Mack basin washers		.25
Sink collar washers		.35
Seat bumpers, per piece		.10
Rubber elbows, each		1.00
Hopper closet connections		.25
Ohliger		.25
Bib washers		.05
Cut washers to 1 inch		.10
Cut washers 1¼ to 2 inches		.20
Cut washers to 3 inches		.40
Cut washers to 4 inches		.50
Cut washers to 5 inches		.75
Rubber basin plugs		.25
Rubber bath plugs		.35
Rubber laundry plugs		.35
Cut washers to 6 inches		1.00
Rubber spray tubing, per foot		.20

DISCS FOR VALVES

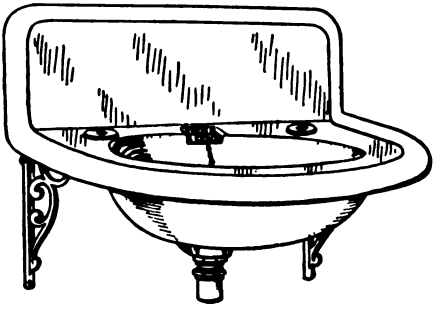
Steam valve discs, ⅜-inch	$0.10
Steam valve discs, ½-inch	.15
Steam valve discs, ¾-inch	.15
Steam valve discs, 1 -inch	.25
Steam valve discs, 1¼-inch	.35
Steam valve discs, 1½-inch	.40
Steam valve discs, 2 -inch	.50

RUBBER DIAPHRAGMS

	High	Low
6-inch	$1.20	$1.00
8-inch	1.30	1.10
9-inch	1.75	1.20
10-inch	2.25	1.50

ENAMELED LAVATORIES

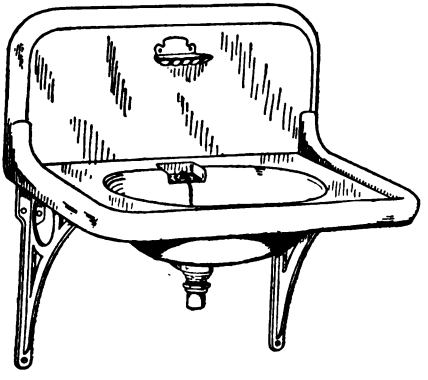
Roll edge slab with 11×15 inch bowl, back, soap cup, patent overflow with removable nickel-plated brass strainer, bronzed iron brackets, nickel-plated plug coupling, and rubber stopper.



Less faucets and trap, 18×21 ..... $11.00

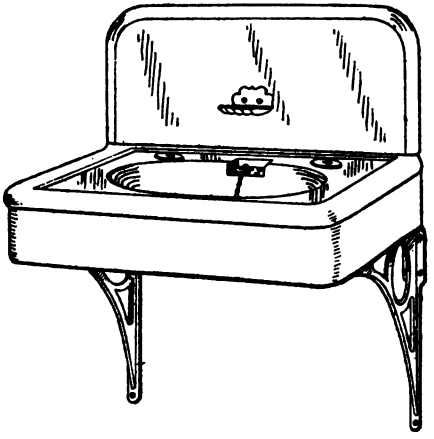
ENAMELED ROLL RIM LAVATORIES

Enameled roll rim lavatory with Columbian basin; 10-inch high back cast in one piece, nickel-plated soap cup, patent overflow with nickel-plated brass strainer; nickel-plated plug coupling, and rubber stopper.



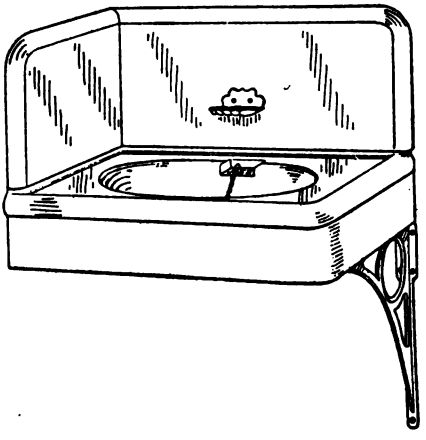
Less faucets and trap, 18×24 ..... $16.00

Enameled roll rim lavatory with patent overflow, oval bowl, and enameled aprons cast in one piece, with 12-inch high enameled roll rim back, soap cup, and two enameled iron brackets.



Less faucets and trap, 20×24 ..... $30.00

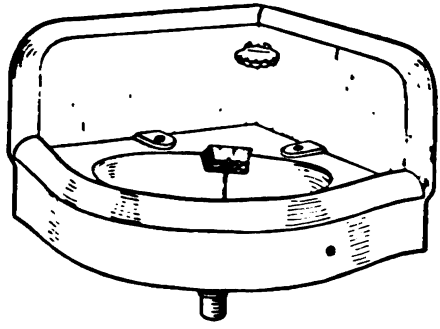
Enameled roll rim lavatory with patent overflow, oval bowl, and enameled aprons cast in one piece, with 12-inch high enameled



roll rim back, soap cup, and left- or right-hand end, with enameled bracket.

Less faucets and trap, 20×24 ..... $30.00

Roll edge slab for corner with apron and backs cast in one piece; 11×15-inch Columbian bowl, soap cup, patent overflow with removable brass strainer, nickel-plated plug, coupling, and rubber stopper, one piece.



Less faucets and trap $17.00

MARBLE LAVATORIES

1¼-inch stock sizes Italian marble, per foot	$2.25
1¼-inch stock sizes Tennessee marble, per foot	2.25

All other kinds of marble in same proportion

EARTHENWARE BASINS

14-inch C.O. basin	$2.75
14-inch P.O.M.P. basin	2.50
14-inch P.O.R.P. basin	2.75
14×17 C.O. basin	4.50
14×17 P.O.M.P. basin	5.50
15×19 C.O. basin	6.50
15×19 P.O.M.P. basin	8.00

BASIN REPAIRS

Chain stays or cock hole plugs	$0.75
⅜-inch wall basin supplies, each, per pair	3.75
½-inch supplies, each, per pair	4.00
Supplies with air chambers, add $2.00 per pair	
Speedy connections, per pair	.75
N.P. Ideal basin waste	7.00
Cock hole covers	.75
Basin clamps	.35
N.P. basin chain, per foot	.10
N.P. basin plugs, C.O.	1.50
N.P. basin plugs, P.O.	1.50
Metal basin plugs, 1¼-inch	.50
Metal basin plugs, 1½-inch	.75
Toggle bolts	.25
Plaster of Paris, per pound	.10

S. hooks	$0.10
Slip snaps	.10
N.P. flanges, brass—	
⅜- and ½-inch	.30
¾-inch	.50
1- and 1¼-inch	.50
1½- and 2-inch	.75

N.P. BRASS FITTINGS, IRON PIPE SIZE

N.P. iron pipe size brass tubing, per foot	List Price
N.P. iron pipe size brass tubing, ⅛-inch, per foot	List Price
N.P. iron pipe size brass tubing, ¼-inch, per foot	List Price
N.P. iron pipe size brass tubing, ⅜-inch, per foot	List Price
N.P. iron pipe size brass tubing, ½-inch, per foot	List Price
N.P. iron pipe size brass tubing, ¾-inch, per foot	List Price
N.P. iron pipe size brass tubing, 1-inch, per foot	List Price
N.P. brass tubing, 1¼-inch, per foot	List Price
N.P. brass tubing, 1½-inch, per foot	List Price
N.P. brass tubing, 2-inch, per foot	List Price

	¼	⅜	½	¾	1	1¼	1½	For Waste 2
Elbows	$0.30	$0.35	$0.50	$0.60	$1.00	$1.35	$1.75	$2.50
Couplings	.35	.40	.55	.75	.80	1.25	1.50	2.00
45-degree ells	.40	.45	.60	.70	1.00	1.50	2.00	3.00
Tees	.45	.50	.70	1.00	1.30	2.00	2.50	3.75
Crosses	.60	.75	1.00	1.30	2.00	2.75	3.50	5.25
Bushings	.20	.25	.35	.40	.60	.90	1.25	1.75
Plugs	.25	.35	.40	.50	.70	.90	1.25	1.75
Caps	.30	.35	.50	.60	.75	1.00	1.30	2.00
Unions	.50	.75	1.00	1.25	1.75	2.50	3.00	4.50

Add 10 cents for all nickel-plated fittings

ROLL RIM ENAMEL BATHTUBS

3-inch rim

4- and 4½-foot	$31.00
5- foot	31.00
5½-foot	35.00
6- foot	45.00

BATHTUB REPAIRS

Enameled tubs with rims larger than 3 inches and all special shapes, also pool, seat, and foot tubs. List price.

	Per Pair
Bath cocks	$5.50
N.P. supplies I.P. size, ½-inch	5.50

	Per Pair
N.P. Conn. W. and overflow, 1¼-inch	$5.00
N.P. bath sprays	.60
N.P. bath spray couplings	.75
N.P. bath showers	List Price
Shower curtain	6.00
Bathtub seats	List Price

URINALS

	Earthenware	Enameled
No. 1	$16.00	$24.00
No. 2	13.00	.....
Siphon jet urinal	22.50	.....

ENAMEL URINAL TROUGHS—LIPPED

Less tank and flush

24	$30.00
36	44.00
48	50.00
Automatic urinal tanks, 2-gallon	16.00
N.P. spray pipe, 24-inch	6.00
N.P. spray pipe, 36-inch	12.00
N.P. spray pipe, 48-inch	12.50
N.P. flush pipe	3.00

URINAL REPAIRS

N.P. Comp. urinal cock	$3.00
N.P. Comp. urinal cock, loose key	3.50
N.P. self-closing cocks	5.00
2-inch beehive strainers	3.00
Urinal wire basket	List Price

COMPETITION CLOSET COMBINATION

Siphon wash down bowl—	
High oak tank, oak seat, N.P. flush	$18.00
Same combination, low-down tank	21.00

WATER CLOSETS

Philadephia enameled iron hopper	$ 3.00
Philadelphia earthenware hopper	6.00
Tall round enameled iron F.R. hopper and coupling	9.00
Tall round earthenware F.R. hopper and coupling	9.00
Tall oval, enameled iron F.R. hopper and coupling	10.00
Tall oval, earthenware F.R. hopper and coupling	11.00

Short round enameled iron, F.R. hopper and coupling	$ 4.75
Oval combined earthenware F.R. hopper and trap	15.00
No. 3 plain earthenware washout closet	12.00
No. 3 plain earthenware washout closet, embossed	14.00
Enameled washout	20.00
Earthenware washdown	11.00
Enameled washdown	20.00
Earthenware siphon washdown with jet	11.00
Enameled siphon washdown with jet	13.00
Earthenware siphon jet	18.00
Enameled siphon jet	23.00

WATER-CLOSET TANKS

Porcelain, low down	$20.00
Enameled, low down	List Price
Competition, low down	18.00
Ordinary 5-gallon hardwood tank	12.50
Siphon jet high tank	20.00
Siphon jet low-down tank	21.00

WATER-CLOSET SEATS

1¼-inch hardwood closet seat and cover	$ 3.50
1¼-inch hardwood closet seat, less cover	2.50
Celluloid seats	18.00
Square oak seats	5.00

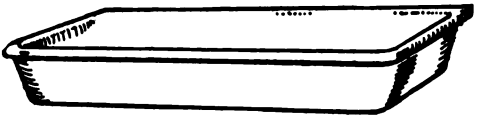
CLOSET REPAIRS

Wooden tank pulls	$0.35
Porcelain tank pulls	1.25
Celluloid tank pulls	1.50
Rubber tank pulls	.65
N.P. flush pipes, 1½- or 1¼-inch slip joint ell extension and strap	6.00
1¼- and 1½-inch slip joint ell	2.25
Rough brass	2.75
Galvanized iron	2.75
N.P. supplies for high tank	7.00
Combination strap and bumper	1.25
Brass closet floor flange and gasket	3.00
Gasket	.50
N.P. brass closet bolts, each	.15
Tank plungers	3.00
Gooseneck plungers	2.00

Copper siphon plungers	$4.00
2-inch N.P. flush offsets	1.75
2-inch N.P. straight flush connection	1.25
2-inch N.P. elbow, low down	2.50

ENAMELED ROLL RIM SINK

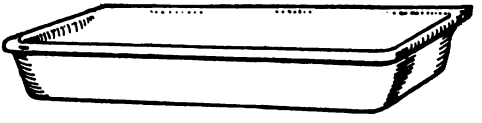
With N.P. strainer and two painted iron legs.



Size of Sink	
16×24	$10.50
18×24	10.75
18×30	11.25
18×36	13.00
20×30	12.75
20×36	13.50
20×40	14.50
22×36	13.25
22×42	15.00

ENAMELED ROLL RIM SINK ON ALL SIDES

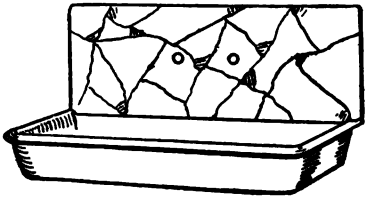
With N.P. strainers and two special brackets.



Size of Sink	
16×24	$12.75
18×24	13.00
18×30	13.50
18×36	14.75
20×30	15.00
20×36	15.25
20×40	16.50
22×36	17.25
22×42	18.00

ENAMELED ROLL RIM SINK

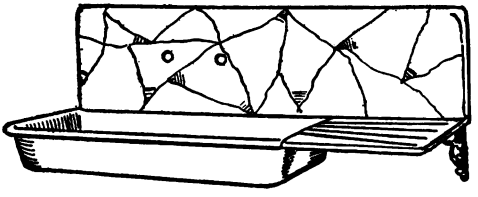
With marble back, N.P. strainers, and two painted iron legs.



Size of Sink	With Italian Marble Back	With Tennessee Marble Back
16×24 with 18-inch high back	$15.50	$15.00
18×24 with 18-inch high back	16.75	16.00
18×30 with 18-inch high back	18.25	17.25
18×36 with 18-inch high back	21.00	20.25
20×30 with 18 inch high back	19.75	19.50
20×36 with 18-inch high back	21.75	20.50
20×40 with 18-inch high back	24.00	22.75
22×36 with 18-inch high back	22.00	21.25
22×42 with 18-inch high back	24.75	23.25

ENAMELED ROLL RIM SINK

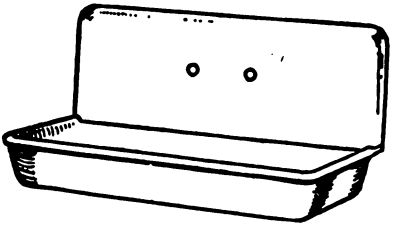
With depressed end, 18-inch high marble back, 1¼-inch marble drain board, drain-board bracket, N.P. strainer, and two painted iron legs.



Size of Sink	Length of Drain Board	Height of Back	With Italian Marble Back	With Tennessee Marble Back
18×36	24	18	$39.00	$35.50
20×30	24	18	39.00	36.00
20×36	24	18	40.50	37.50
20×40	24	18	42.75	39.25
22×36	24	18	43.00	39.75
22×42	24	18	45.00	41.62

ENAMELED ROLL RIM SINK WITH BACK

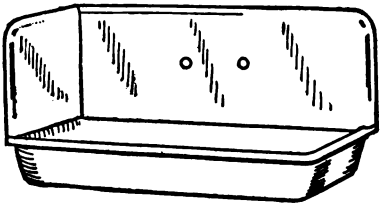
With 15-inch high back, N.P. strainer, and two painted iron legs.



Size of Sink	
16×24	$15.00
18×24	16.00
18×30	18.00
18×36	20.00
20×30	21.50
20×36	23.50
20×40	28.00
22×36	26.00
22×42	30.00

ENAMELED ROLL RIM SINK WITH BACK AND END

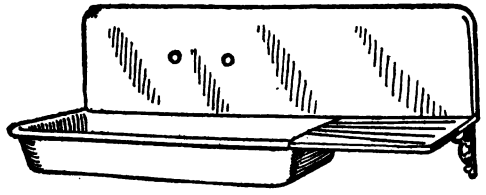
With 15-inch high back end piece, N.P. strainer, and one painted iron leg.



Size of Sink	
18×30	$25.00
20×30	27.00
20×36	30.00
20×40	38.00
22×36	38.00
22×42	42.00

ENAMELED ROLL RIM SINK WITH DEPRESSED END

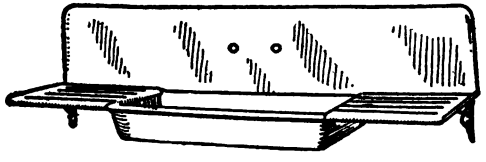
With 15-inch long back, enameled or wooden drain board with bracket, N.P. strainer, and two painted iron legs.



Size of Sink	With Enameled Drain Board	With Ash Drain Board
16×24 with 24-inch long drain	$28.50	$25.75
18×24 with 24-inch long drain	29.50	27.00
18×30 with 24-inch long drain	31.50	28.75
18×36 with 24-inch long drain	33.75	31.50
20×30 with 24-inch long drain	33.00	31.00
20×36 with 24-inch long drain	43.00	32.50
20×40 with 24-inch long drain	37.50	34.75
22×36 with 24-inch long drain	37.50	33.25
22×42 with 24-inch long drain	39.75	35.50
16×24 with 18-inch long drain	26.50	24.00
18×24 with 18-inch long drain	27.75	25.50
18×30 with 18-inch long drain	29.50	27.00
18×36 with 18-inch long drain	31.25	29.25
20×30 with 18-inch long drain	34.00	28.50
20×36 with 18-inch long drain	36.25	30.75
20×40 with 18-inch long drain	36.25	33.00
22×36 with 18-inch long drain	35.50	31.50
22×42 with 18-inch long drain	37.75	33.75

ENAMELED ROLL RIM SINK WITH DOUBLE DRAIN BOARD

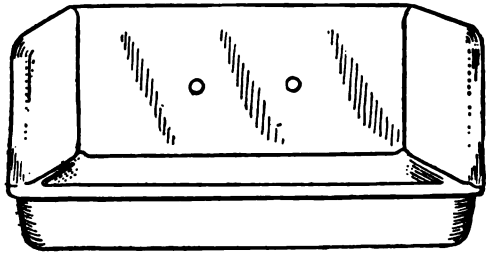
Sink depressed at both ends, with 15-inch high long back and two drain boards, drain-board brackets, N.P. strainer, and two painted iron legs.



Size of Sink	With Enameled Drain Boards	White Ash Drain Boards
18×30 with 2 18-inch drain boards	$39.75	$34.50
18×36 with 2 18-inch drain boards	42.00	36.75
20×30 with 2 18-inch drain boards	42.25	36.00
20×36 with 2 18-inch drain boards	45.00	38.25
20×40 with 2 18-inch drain boards	37.25	40.50
22×36 with 2 18-inch drain boards	37.25	39.00
22×42 with 2 18-inch drain boards	49.50	41.25

ENAMELED ROLL RIM SINK FOR RECESS

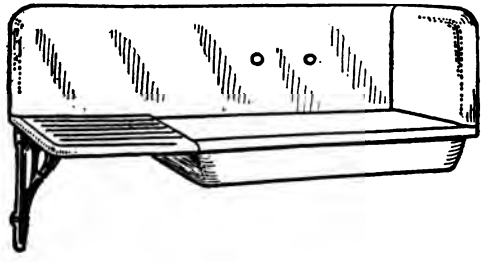
With 15-inch high back and two ends, N.P. strainer.



Size of Sink	
18×30	$17.00
18×36	18.50
20×30	18.50
20×36	20.00
20×40	21.50
22×36	21.00
22×42	22.50

ENAMELED ROLL RIM SINK, LONG BACK AND END PIECE

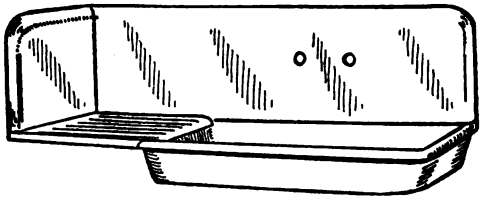
Right or left; 13-inch high, long back, right end piece, enameled or wooden drain board, with bracket, N.P. strainer, and one painted iron leg.



Size of Sink	With Enameled Drain Board	With Ash Drain Board
18×30	$34.75	$32.25
18×36	37.00	34.50
20×30	38.00	34.00
20×36	39.75	36.25
20×40	42.00	38.50
22×36	41.00	37.50
22×42	43.75	39.75

ENAMELED ROLL RIM SINK, WITH LONG BACK AND END PIECE

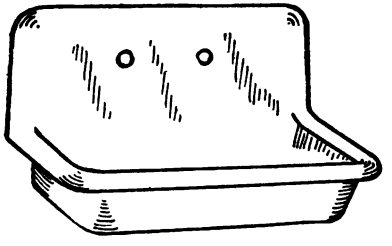
With 15-inch high, long back and end piece, enameled or wooden drain board, N.P. strainer, and two painted iron legs.



Size of Sink	With Enameled Drain Board	With Ash Drain Board
18×30	$36.00	$33.25
18×36	38.25	35.50
20×30	38.25	34.75
20×36	39.50	37.00
20×40	42.75	39.25
22×36	42.00	37.75
22×42	44.25	40.00

ONE-PIECE SINK AND BACK

White enameled sink and back, integral, with two iron legs.

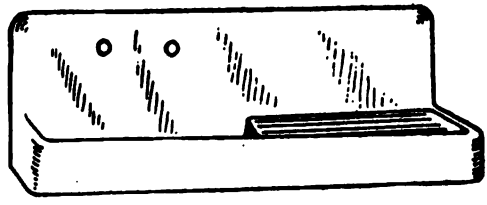


20×30 ..... $18.00

Reversible drain board and faucet extra

ONE-PIECE SINK AND LONG BACK DRAIN BASIN AND APRON

With white enameled sink back and two iron legs.



20×30, 18-inch drain board	$40.00
20×30, 24-inch drain board	60.00

Faucet extra

DRAIN BOARDS

For depressed sink, also reversible drain board.

	Enameled
For 18-inch sink, each	$6.75
For 24-inch sink, each	8.50
Ash or oak drain boards	3.00

ENAMELED SINK OR DRAIN BOARD ENDS

12 inches high

For 18-inch sink	List Price
For 20-inch sink	List Price
For 24-inch sink	List Price

15 inches high

For 18-inch sink	List Price
For 20-inch sink	List Price
For 24-inch sink	List Price

ENAMELED IRON ROLL RIM SINK BACKS

15 inches high, 2½ inches deep

24-inch back only	List Price
30-inch back only	List Price
36-inch back only	List Price
42-inch back only	List Price
48-inch back only	List Price
54-inch back only	List Price
60-inch back only	List Price
66-inch back only	List Price
72-inch back only	List Price

12 inches high, 2¼ inches deep

24-inch back only	List Price
30-inch back only	List Price
36-inch back only	List Price
40-inch back only	List Price
42-inch back only	List Price

12 inches high, 1¼ inches deep

24-inch back only	List Price
28-inch back only	List Price
30-inch back only	List Price
32-inch back only	List Price
36-inch back only	List Price
40-inch back only	List Price
42-inch back only	List Price
48-inch back only	List Price

SINK BRACKETS

16×16	List Price
16×18	List Price
16×20	List Price

PLAIN SINKS

	Painted	Enameled
12×18	$3.50	$ 7.00
16×24	....	....
18×30	....	7.00
18×36	3.75	10.50
20×30	5.00	8.25
20×36	4.60	11.00
20×40	5.50	15.00
22×42	6.50	16.50
22×48	8.00	12.00

SQUARE SLOP SINKS

	Plain	Enameled
16-16-10	$4.25	$ 9.00
20-16-12	6.00	12.00
30-20-12	7.00	14.00

ROLL RIM SLOP SINKS WITH BACK, TRAP STANDARD INCLUDING COCKS

18-22-12	$40.00
20-30-12	45.00

If with one end piece, add $4.00

SINK REPAIRS

Sink collar, threaded	$0.50
Sink collar	.35
Sink strainer	.35
Sink bolts, each	.10
Drain-board clamps	.30

LAUNDRY TUBS—NO BACKS INCLUDED

Complete with legs, cocks, and plugs.

2 part granitine	$15.00
3 part granitine	20.00
2 part 4-foot soapstone	25.00
2 part 4½-foot soapstone	28.00
3 part 6-foot soapstone	40.00

MISCELLANEOUS

Cartage, per mile	$1.00
Candles, each	.10
Gasoline, per gallon	.25
Putty, per pound	.05

LABOR

Superintendent, per hour	$1.35
Plumber, per hour	1.10
Gas fitter, per hour	1.10
Plumber's laborer, per hour	.75
Plumber's helper, per hour	.50

Overtime to be charged at the rate of double time

GAS GOODS

Stiff gilt brackets	$0.50
Single-swing gilt brackets	.75
Double-swing gilt brackets	1.20
Three-swing gilt brackets	1.65
Universal one-swing brackets	1.65
Universal two-swing brackets	2.10
Universal three-swing brackets	2.50
Stiff square polish brass brackets	.90
Stiff square curved brass brackets	1.00
Single-swing square brass brackets	1.45
Double-swing square brass brackets	1.85
Three-swing square brass brackets	2.50
¼- and ⅜-inch T-handle gas cocks, each	.75
½-inch T-handle gas cocks, each	.85
Independent cocks	.40

4-inch globe holder	$0.25
5-inch globe holder	.30
Pillar burner	.15
Lava tips, each	.02½
Aluminum tips, each	.05

GAS HOSE

Foot	$0.12

GAS HOSE COCKS

⅜-inch	$0.25
½-inch	.30
¾-inch	.40
El burner cocks, ⅛- and ¼-inch	.25
El burner cocks, ⅜-inch	.30
Pillar cocks, ⅛- and ¼-inch	.25
Pillar cocks, ⅜-inch	.30

SEWER PIPE AND FITTINGS

4-inch sewer pipe, per foot	$0.20
6-inch sewer pipe, per foot	.30
9-inch sewer pipe, per foot	.50

TRAPS

4-inch trap	$1.50
6-inch trap	2.25

ELLS OR CURVES

4-inch ells or curves, each	$0.50
6-inch ells or curves, each	.85
9-inch ells or curves, each	1.50

BRANCHES

4-inch Y or T branches, each	$0.75
6-inch Y or T branches, each	1.00
9-inch Y or T branches, each	1.70

CATCH-BASIN COVERS

2½-foot stone cover, with iron or concrete center	$5.00
3 -foot stone cover, with iron or concrete center	6.00
Iron centers for stone covers	List Price
All iron catch-basin covers	List Price
Cleaning catch basins	List Price
Back-water valve combinations and fittings	List Price
Cast-iron drainage fittings of a special design or manufacture	List Price

Cartage and carfare to be charged

TILE BASINS

9-inch tile basins	$ 5.00
12-inch tile basins	7.00
15-inch tile basins	9.00
18-inch tile basins	12.00

DRAIN TILE

3-inch drain tile, per foot	$0.10
4-inch drain tile, per foot	.12
20-inch iron covers and rings for drain tile basins	5.00

HEAVY CAST-IRON COVERS

Corporation catch-basin or manhole covers, each	$ ....
Suburban covers, each	....
Sealed catch-basin covers, each	....

CEMENT

Portland cement, per bag	$1.00
Portland cement, per pail	.50
Utica cement, per barrel	2.50
Utica cement, per pail	.25

LABOR

Pipe layer, per hour	$0.90
Laborer, per hour	.70

Use of Table III. The method of using Table III is quite obvious, but a word of explanation may be desirable. The larger multiplier is chosen from the heavy numbers at the left, and the other multiplier is found in the upper tier of numbers at the right of the first multiplier. The product of the two numbers is directly below this second number. For example, to find the product of 17 and 15, locate 17 at the left and follow horizontally to 15 in the upper tier. The number just below, 255, is the required product.

ACTUAL ESTIMATES

The taking off of quantities and the making up of an actual estimate is the end toward which our efforts are now directed, but, before we are capable of doing this efficiently, it is essential to acquire a thorough knowledge of plans, sections, elevations, and scales.

TABLE III.

Rapid Multiplication Table from 1 to 25

1																								
2	2	4																						
3	2	3	6	9																				
4	2	3	4	8	12	16																		
5	2	3	4	5	10	15	20	25																
6	2	3	4	5	6	12	18	24	30	36														
7	2	3	4	5	6	7	14	21	28	35	42	49												
8	2	3	4	5	6	7	8	16	24	32	40	48	56	64										
9	2	3	4	5	6	7	8	9	18	27	36	45	54	63	72	81								
10	2	3	4	5	6	7	8	9	10	20	30	40	50	60	70	80	90	100						
11	2	3	4	5	6	7	8	9	10	11	22	33	44	55	66	77	88	99	110	121				
12	2	3	4	5	6	7	8	9	10	11	12	24	36	48	60	72	84	96	108	120	132	144		
13	2	3	4	5	6	7	8	9	10	11	12	13	26	39	52	65	78	91	104	117	130	143	156	169
14	2	3	4	5	6	7	8	9	10	11	12	13	14	28	42	56	70	84	98	112	126	140	154	168	182	196
15	2	3	4	5	6	7	8	9	10	11	12	13	14	15	30	45	60	75	90	105	120	135	150	165	180	195	210	225
16	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	32	48	64	80	96	112	128	144	160	176	192	208	224	240	256
17	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	34	51	68	85	102	119	136	153	170	187	204	221	238	255	272	289
18	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	36	54	72	90	108	126	144	162	180	198	216	234	252	270	288	306	324
19	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	38	57	76	95	114	133	152	171	190	209	228	247	266	285	304	323	342	361
20	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400
21	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357	378	399	420	441
22	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	44	66	88	110	132	154	176	198	220	242	264	286	308	330	352	374	396	418	440	462	484
23	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	46	69	92	115	138	161	184	207	230	253	276	299	322	345	368	391	414	437	460	483	506	529
24	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	48	72	96	120	144	168	192	216	240	264	288	312	336	360	384	408	432	456	480	504	528	552	576
25	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	50	75	100	125	150	175	200	225	250	275	300	325	350	375	400	425	450	475	500	525	550	575	600	625

Definitions. *Plan.* A plan of a building is a section cut by a horizontal plane through the walls, supports, etc., at a height to show the greatest number of peculiarities in the construction of walls, doors, windows, supports, columns and pilasters, fire-

places, radiators, plumbing fixtures, drains, etc. It is possible to consider a plan as a horizontal impression that could be taken of the building in the course of construction when it has arrived at a certain level in the height of a story. On the plan, the construction is shown invariably by horizontal sections, but it is possible to project up all that is below and also to show what is above. In the first case, the plan will show the architectural parts which project beyond the base of the walls or supports, such as the base, steps, approaches, etc. In the other case, it will show vaultings, ceilings, entablatures, cornices, etc. Sometimes it is desirable to show both, one-half of each, provided the parts shown are sufficiently interesting or are necessary in explaining the entire scheme. Fig. 11 is the basement plan of a colonial residence of wood construction; Fig. 12 is the first-floor plan; Fig. 13, the second-floor plan; Fig. 14, the roof plan; and plan details are shown in Fig. 15.

Section. The section is a plane cut through the building vertically, that is, it is the same thing perpendicularly that the plan is horizontally. A single section rarely is sufficient to give all the interior of the building; it is necessary to have at least two, one a longitudinal section, perpendicular, as a rule, to the façade, and the other a transverse section, usually parallel to the façade. Very often a small section of the front alone is made. This preferably should be called a *profile* of the front. A transverse sectional view of a colonial house showing the installation of plumbing and heating is illustrated in Fig. 16. A longitudinal and transverse section of a grease trap is shown in Fig. 17.

Elevation. The elevations of a building are the projections of the building on vertical planes parallel to one side of the building on which an elevation is desired. Except in the case of complete uniformity, it is necessary to have several elevations in order to show the complete exterior of a building, such as the principal façade, side elevations, and rear elevation. The front and side elevations of the aforementioned residence are shown in Figs. 18 and 19, while the plumbing plan and section are shown in Fig. 20.

A perspective view of high- and low-pressure condensation connections to a high-pressure boiler is shown in Fig. 21, and a

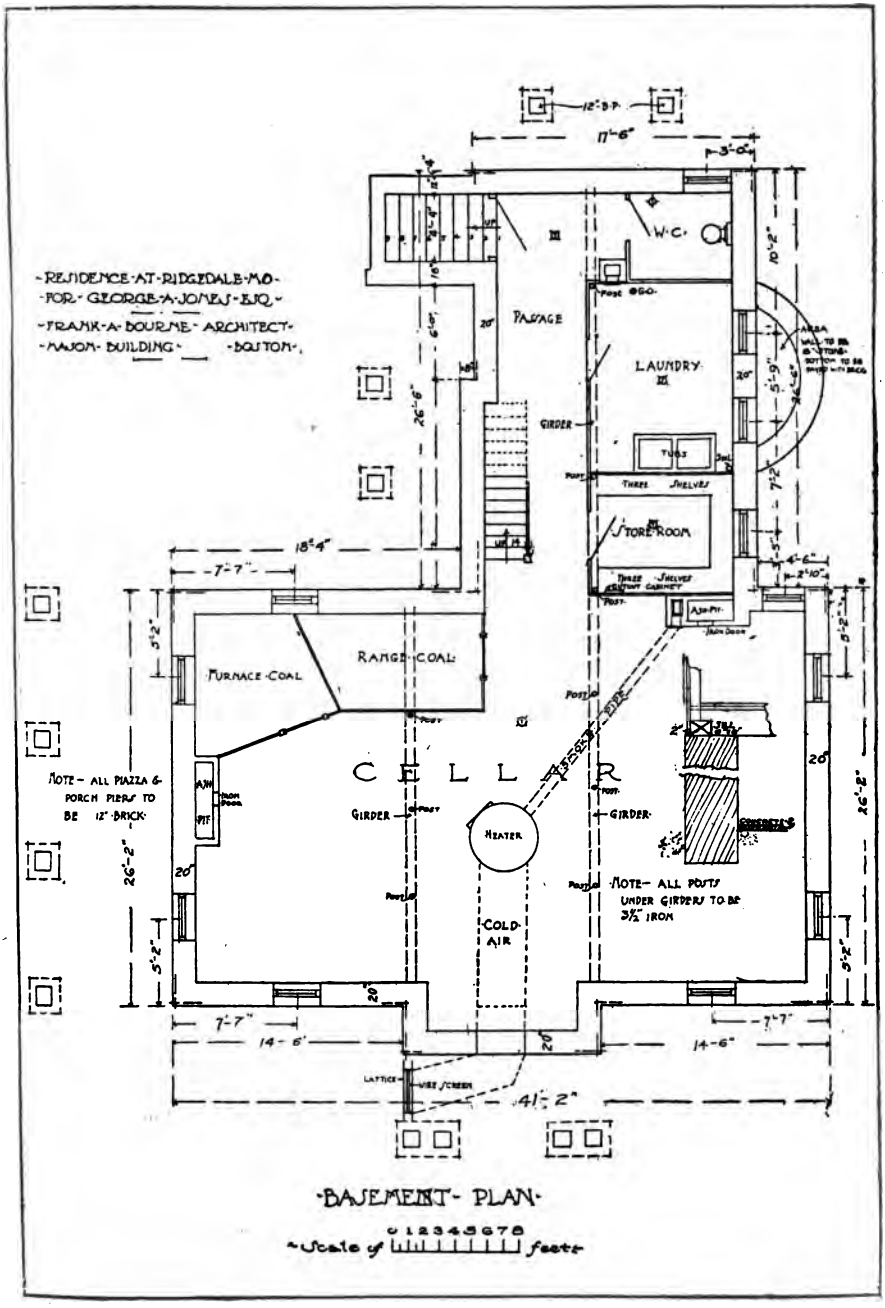


Fig. 11. Basement Plan of Colonial Residence

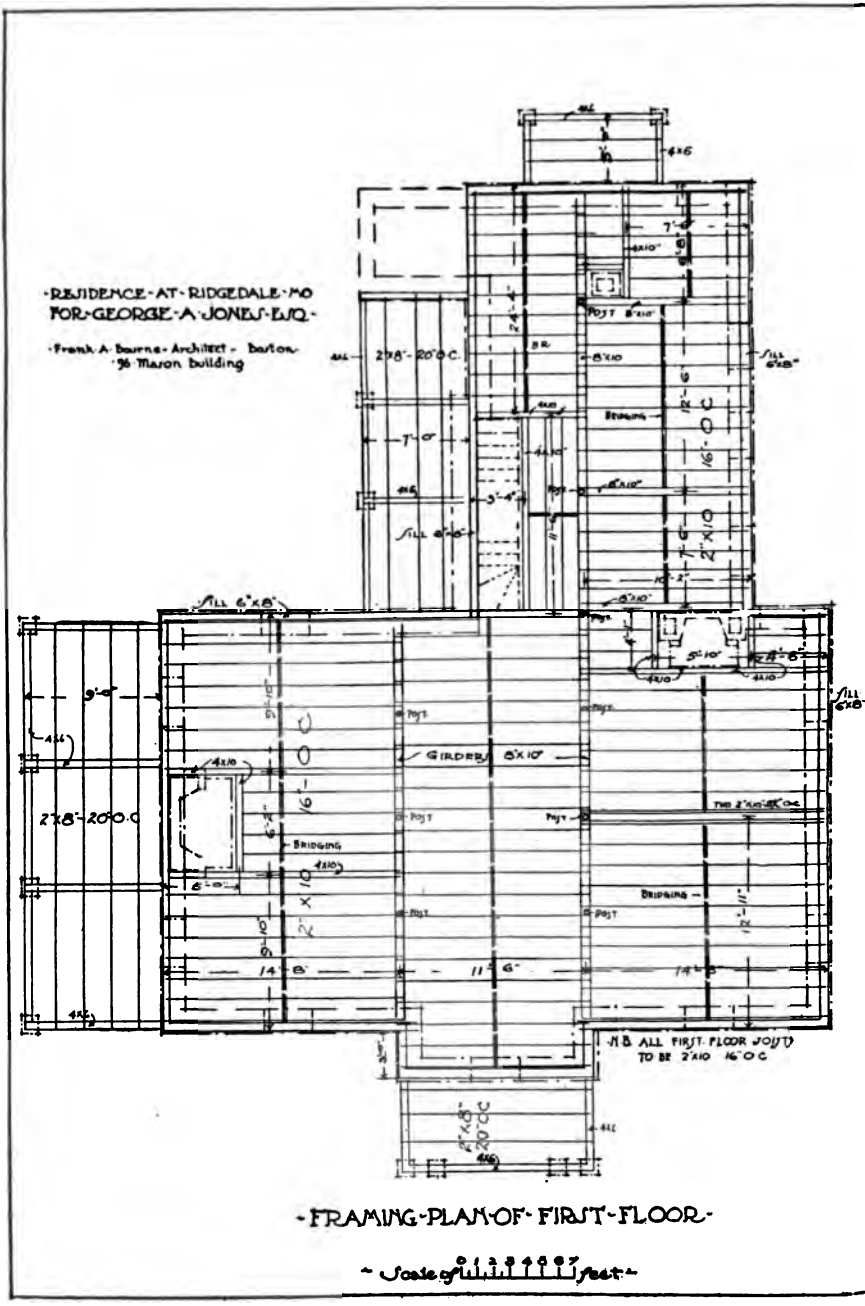

RESIDENCE AT RIDGEDALE MO
FOR GEORGE A JONES ESQ
Frank A Bourne Architect Boston
36 Mason building
2"X8" 20" O.C.
GIRDER 8"X10"
BRIDGING
N.B. ALL FIRST FLOOR JOIST TO BE 2"X10" 16" O.C.
FRAMING PLAN OF FIRST FLOOR
Scale of feet

Fig. 12. First Floor Plan of Colonial Residence

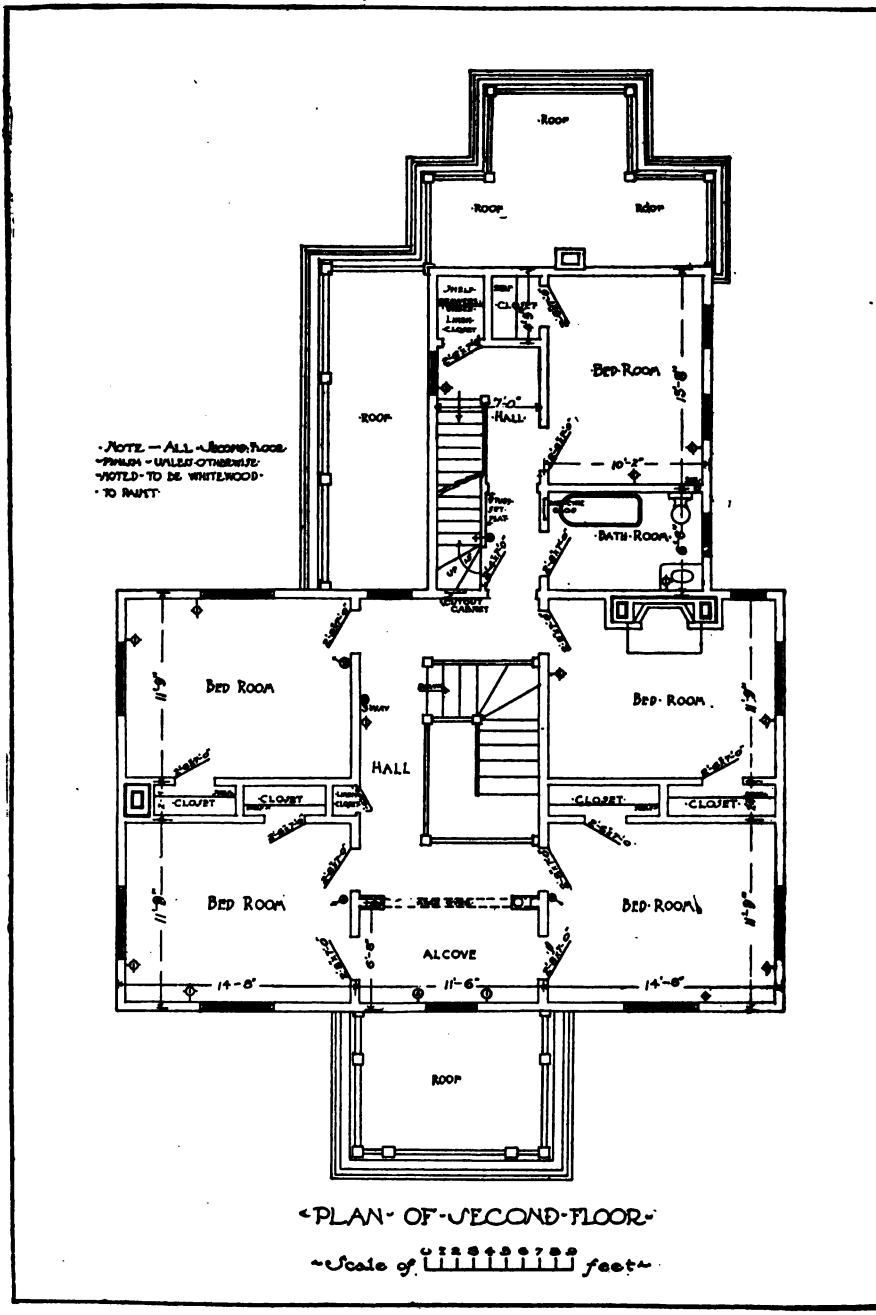


Fig. 13. Second Floor Plan of Colonial Residence

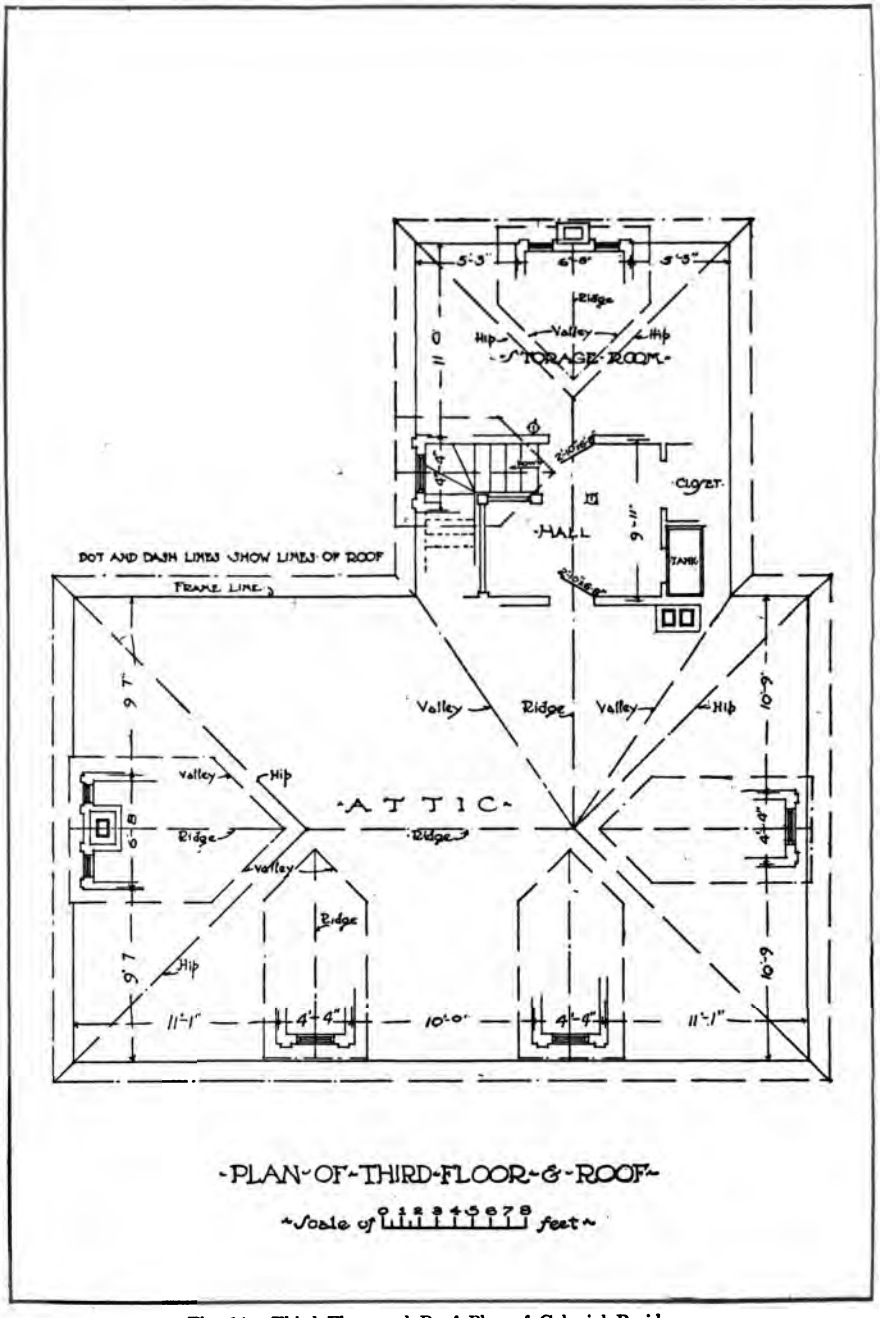


Fig. 14. Third Floor and Roof Plan of Colonial Residence

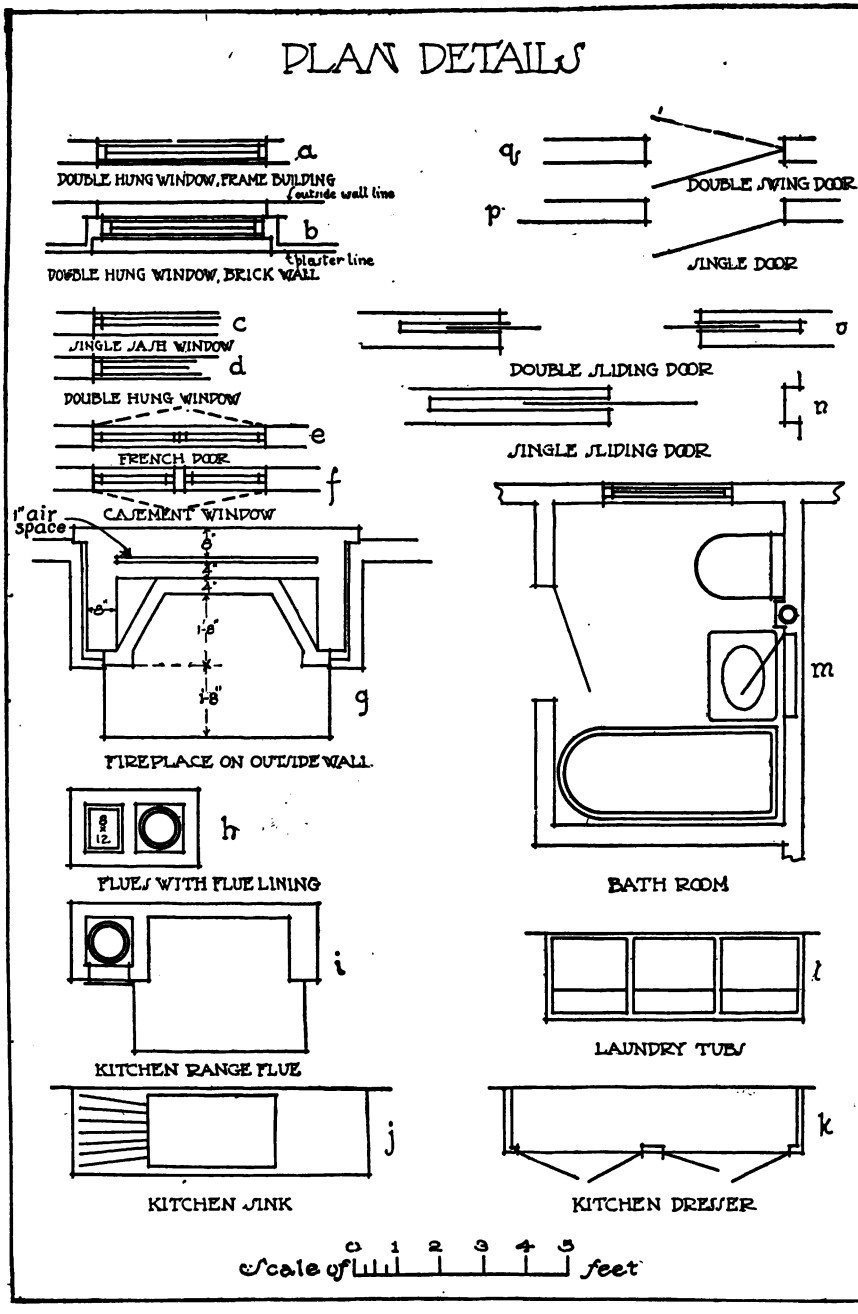


Fig. 15. Enlarged Details of Architectural Features of Colonial Residence

Fig. 16. Transverse Sectional View of Colonial Model House Showing Installation of Heating Plant

perspective view of the necessary wastes and vents for a system of plumbing is illustrated in Fig. 22. Perspective views are most helpful in preparing accurate estimates.

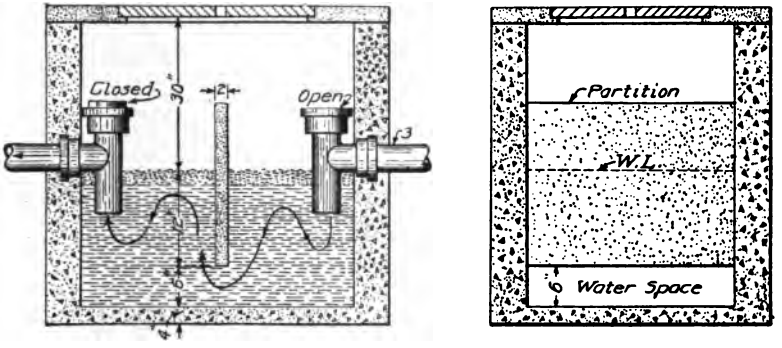


Fig. 17. Longitudinal and Transverse Section of Grease Trap

A combination of plan, section, and elevation is shown in a method of making pipe connections for exhaust steam heating, Fig. 23.

MEASURING-UP WORK

Scales Used. The word "scale" has been used to designate a measure of distance, for example, a scale of $\frac{1}{4}$ inch to one foot.

Scales for architectural work are usually $\frac{1}{4}$ inch to one foot for working drawings and $\frac{3}{4}$ inch to one foot for details, though some offices use $\frac{3}{8}$ inch to one foot, with $\frac{1}{2}$ inch to one foot for details.

One and one-half inches to the foot, one inch to the foot, and three inches to the foot are also used. For the scale of three inches to the foot, the ordinary quarter-inch scale may be read as inches instead of feet, as one-quarter inch is one-twelfth of three inches. The three-quarter inch scale is the favorite among carpenters for the reason that the ordinary two-foot rule can be used on the drawings; as there are twelve-sixteenths of an inch in every three-quarters of an inch, each sixteenth of an inch on the rule represents one inch actual measurement. The inch scale is very popular for drawing mantels, interior finish, etc., where the total dimensions can be read directly from the two-foot rule, each inch being equal to the full size foot.

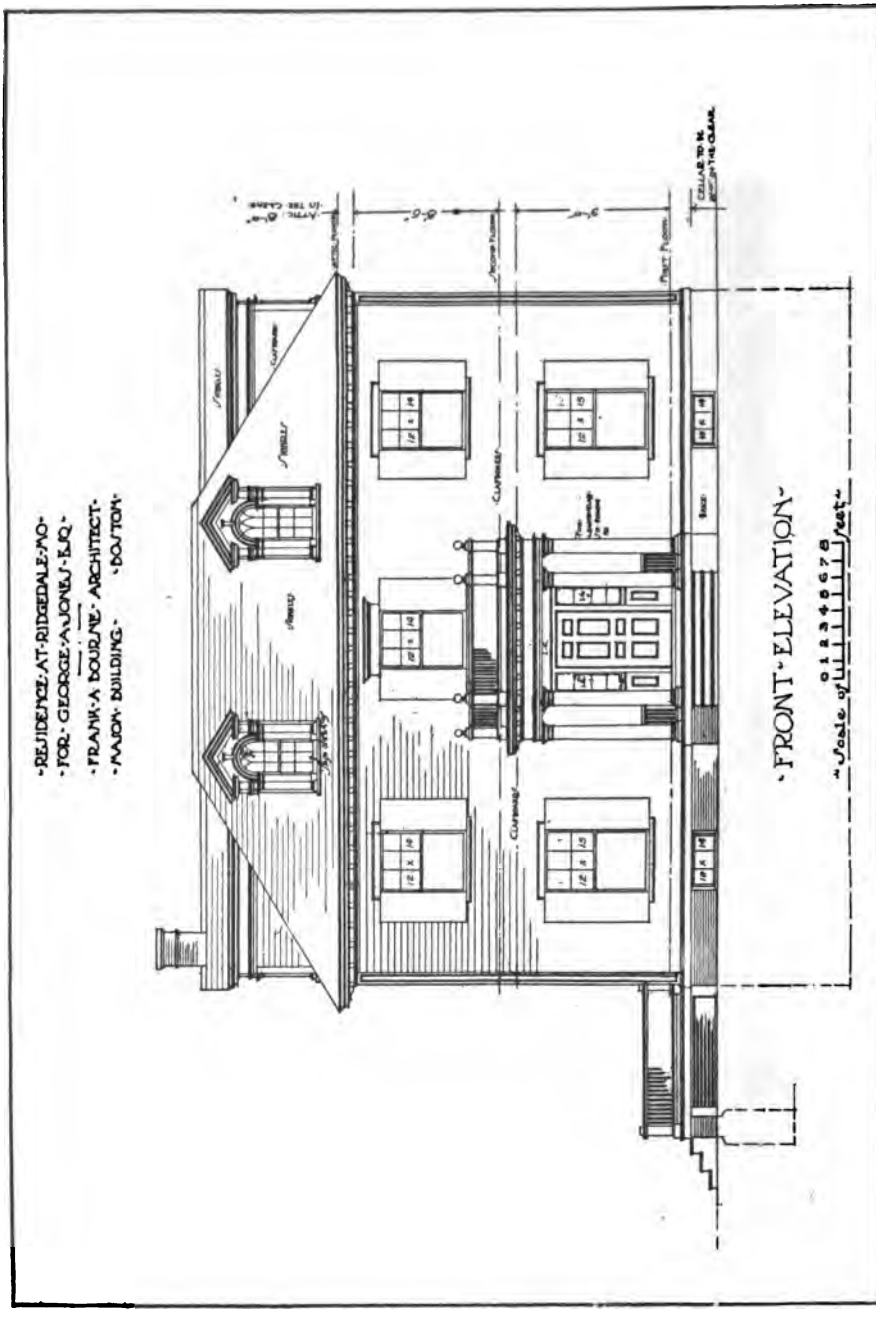

RESIDENCE AT RIDGEDALE MO
FOR GEORGE A JONES ESQ
FRANK A BOURNE ARCHITECT
MASON BUILDING BOSTON
FRONT ELEVATION
Scale of Feet
0 1 2 3 4 5 6 7 8

Fig. 18. Front Elevation of Colonial Residence

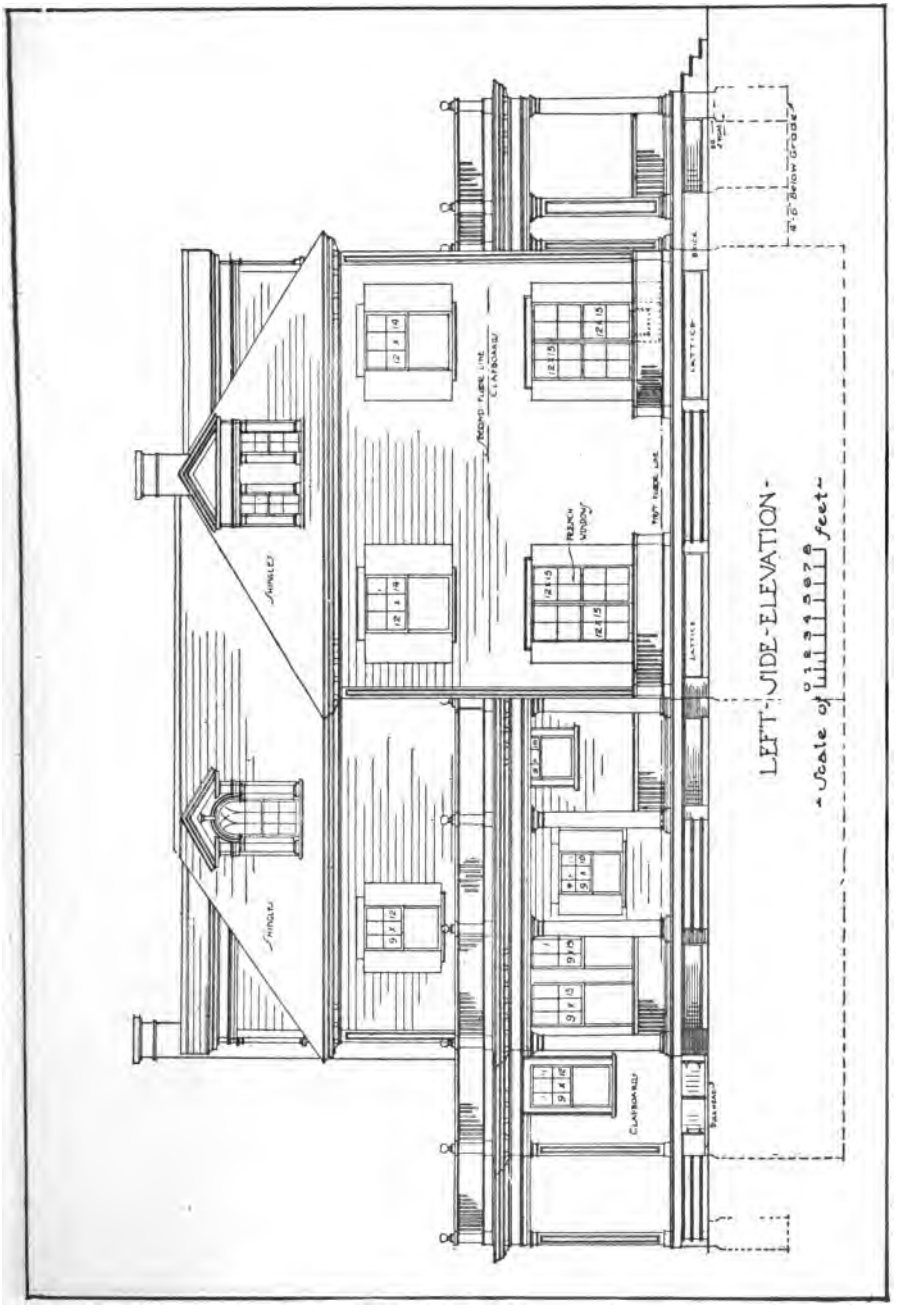


Fig. 19. Left Side Elevation of Colonial Residence

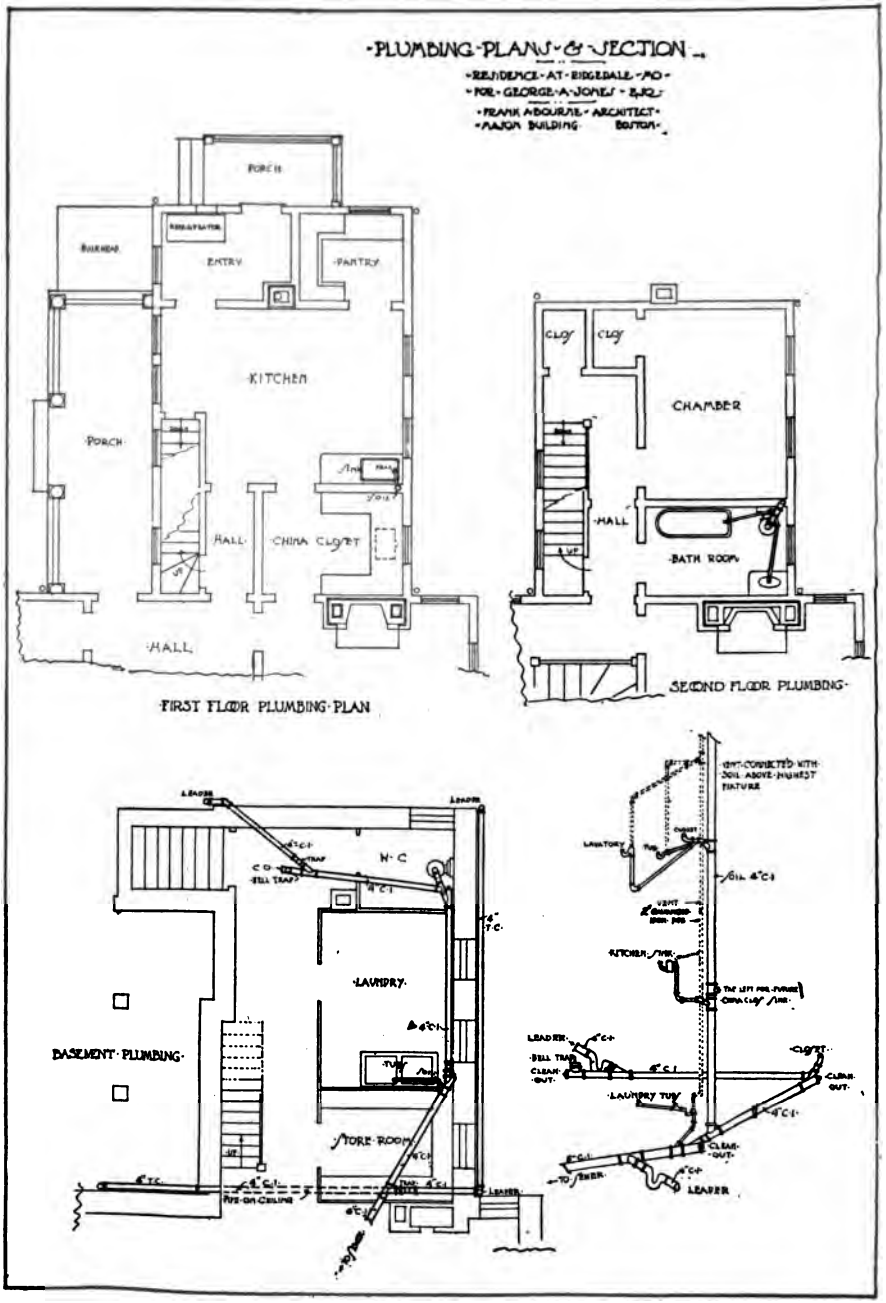


Fig. 20. Plumbing Plans and Section of Colonial Residence

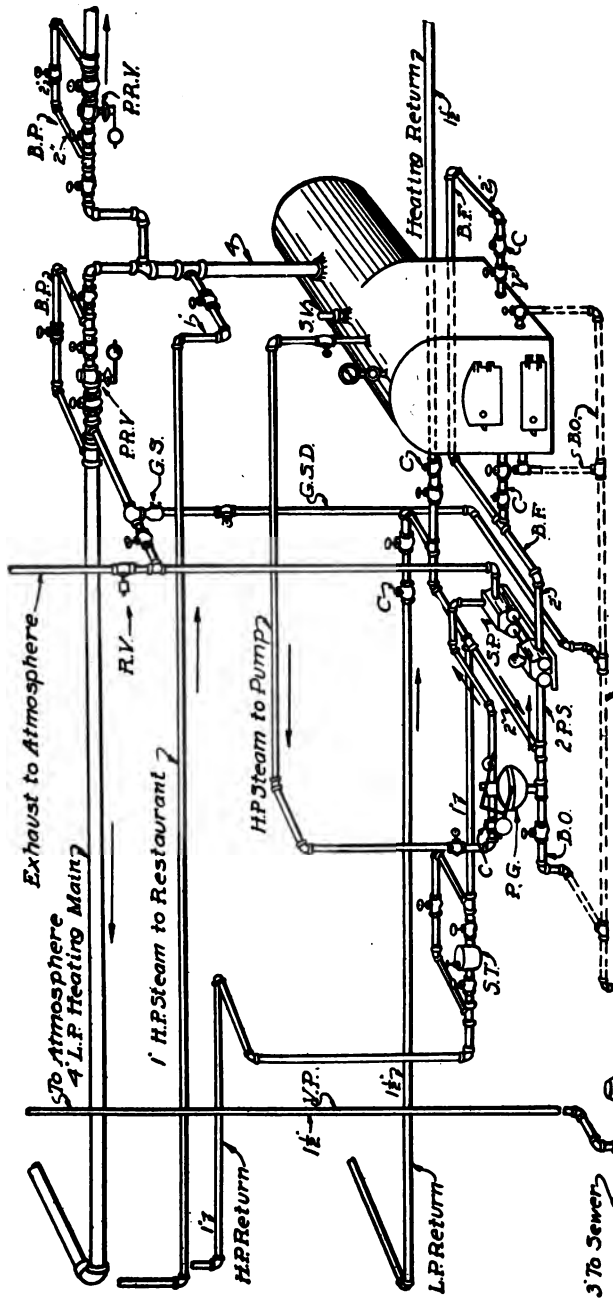


Fig. 21. Perspective View of Pipe Layout Showing High- and Low-Pressure Condensation Connections to High-Pressure Boiler

The illustration, Fig. 24, of an architect's scale shows the usual divisions on a scale for ordinary architectural work. A six-

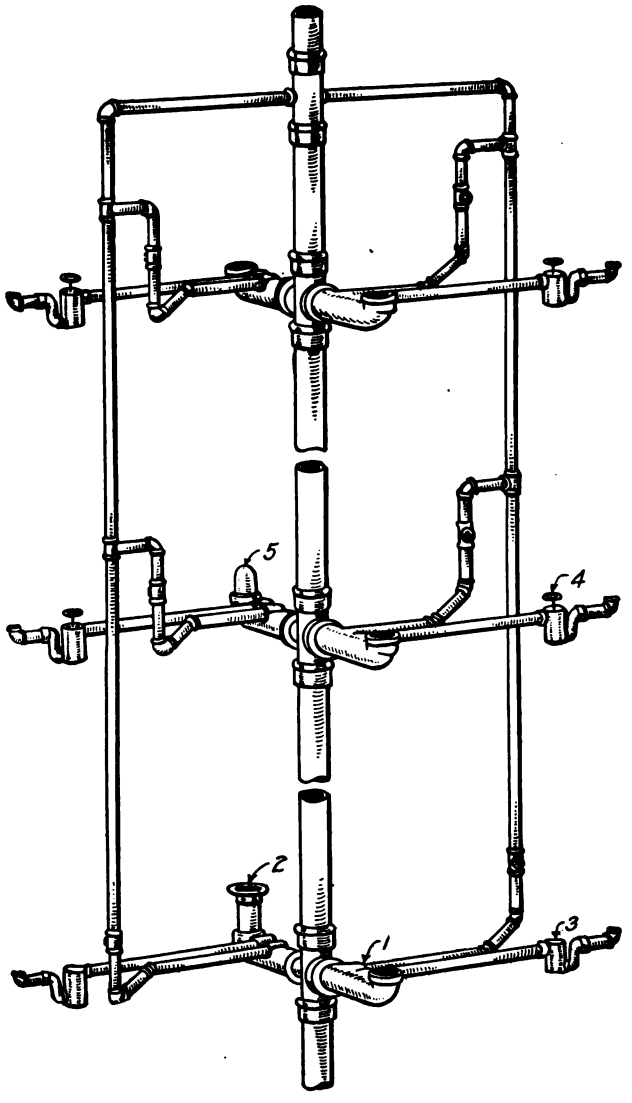


Fig. 22. Perspective View of Necessary Vents for Plumbing System

inch scale of this size is very convenient for ordinary measurements and a similar one eighteen inches or two feet long is useful for

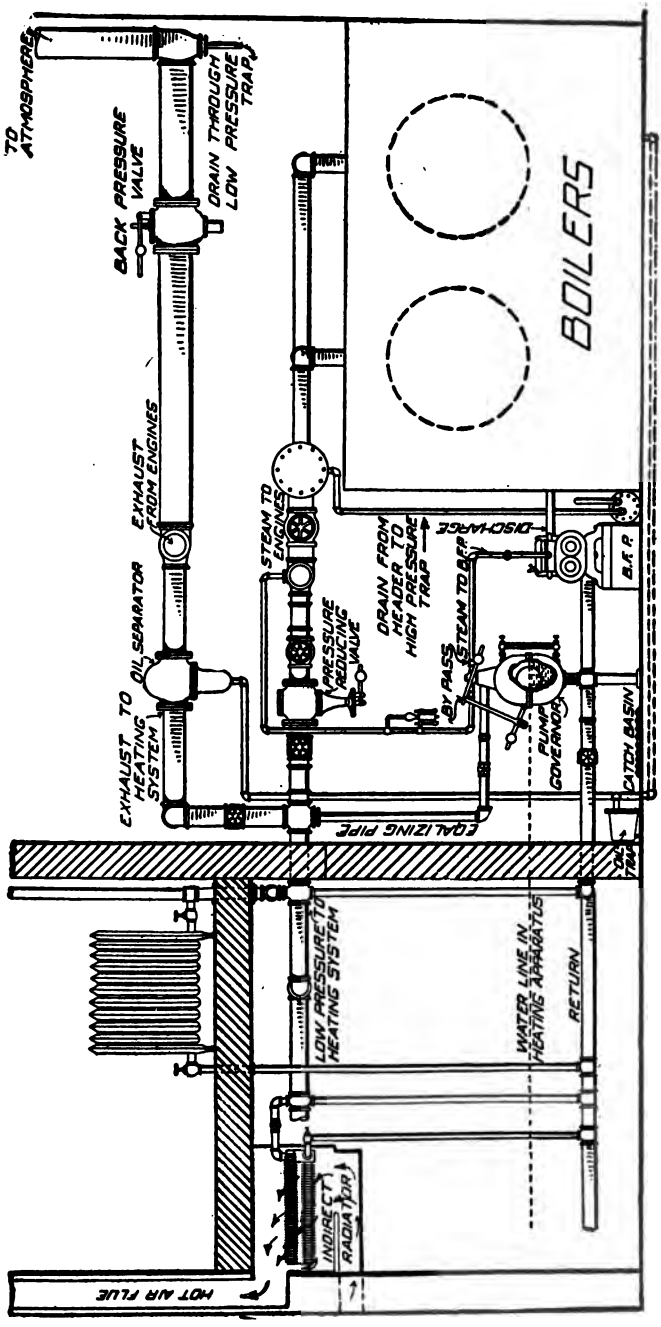


Fig. 23. Layout Showing Method of Making Pipe Connections for Exhaust Steam Heating System

laying out larger work. This scale gives the full size measurements in inches divided into sixteenths with the scales of sixteenths reading in the reverse order from zero up, so that the number can be read directly from a sixteenth-inch scale or doubled for a thirty-second inch scale. The common quarter-inch and eighth-inch scales are given as well as the half-inch and one-inch scales.

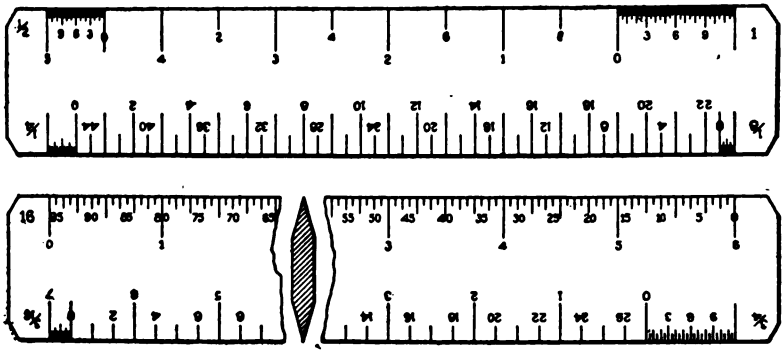


Fig. 24. Typical Architect's Scale

The useful three-quarter inch scale is given with the three-sixteenths scale in reverse order.

Quantities and Prices

We will not burden the student with a mass of figures covering every branch of the building trades, but will proceed to take off the quantities and prepare our estimate for the heating and plumbing from the plans of the colonial residence previously described. Many of our leading estimators commence with the first item on the specification and take off each item as they come to it.

The heating of a building is generally made the subject of a special contract. The three usual methods for house heating are the hot-air furnace, the hot-water boiler; and the steam boiler. Sometimes a combination system of hot air and steam or hot air and hot water is used.

Estimates of the cost of heating should be obtained from contractors who follow this particular branch of construction. In general, for an ordinary class of building, such as residences, apartments, stores, etc., the cost of heating will range, according to the system used, from 6 per cent to 12 per cent of the cost of

the building; the approximate cost of the hot-air furnace will be from 6 to 7 per cent; of steam from 8 to 10 per cent; and of hot water from 10 to 12 per cent.

Hot-Air Heating

Quantities. The hot-air heating of an ordinary house is determined on the basis of the cubic contents to be heated; the area of the piping and the capacity of the furnace can be closely approximated by means of the following general rule:

To determine the size of pipe for any room, *find the contents of the room in cubic feet and divide this by 25 for rooms on the first floor and 35 for rooms on the second and third floors.*

Example. Determine the piping for a house according to the following dimensions.

Solution. The piping for both first and second floor rooms will be as follows:

First Floor Rooms—

Living-room (dimensions 12×15×9)

$(12\times15\times9)\div25=1{,}624\div25=65$ sq. in. area of pipe

$=9$ in., diameter of pipe

Hall (8×20×9; 40 per cent to be added for second story hall)

$(8\times20\times9)\div25=1{,}440\div25=58$ sq. in.

58 sq. in. +23 sq. in. (40 per cent) = 81 sq. in., area of pipe

$=10$ in., diameter of pipe

Dining-room (14×15×9)

$(14\times15\times9)\div25=1{,}890\div25$ $=76$ sq. in., area of pipe

$=10$ in., diameter of pipe

Second Floor Rooms—

Chamber ($13\times15\times8\frac{1}{2}$)

$(13\times15\times8\frac{1}{2})\div35=1{,}658\div35=48$ sq. in., area of pipe

$=8$ in., diameter of pipe

Chamber ($11\times12\times8\frac{1}{2}$)

$(11\times12\times8\frac{1}{2})\div35=1{,}122\div35=32$ sq. in., area of pipe

$=7$ in., diameter of pipe

Chamber ($14\times16\times8\frac{1}{2}$)

$(14\times16\times8\frac{1}{2})\div35=1{,}904\div35=55$ sq. in., area of pipe

$=8$ in., diameter of pipe

Bathroom ($8\times10\times8\frac{1}{2}$)

$(8\times10\times8\frac{1}{2})\div35=680\div35=20$ sq. in., area of pipe

$=7$ in., diameter of pipe

The whole piping area will be as follows:

Two 10-in. pipes	$=2\times78=$	156 sq. in.
One 9-in. pipe	$=$	64 sq. in.
Two 8-in. pipes	$=2\times50=$	100 sq. in.
Two 7-in. pipes	$=2\times38=$	76 sq. in.
Total		396 sq. in.

Cost. A furnace to carry, say, 400 to 500 square feet of pipe area will cost, set in place, from $125 to $150. The labor on pipes, registers, and furnace will be from $25 to $30.

The cost of piping depends on the distances to run, but the material can be estimated according to the schedule given below. Round *tin pipes* will cost, from A. A. charcoal plates, as follows:

Items in Cost	Size of Pipe (inches)											
	6	7	8	9	10	11	12	13	14	15	16	18
Pipe, per ft.....	$0.13	$0.14	$0.15	$0.17	$0.18	$0.23	$0.25	$0.27	$0.29	$0.31	$0.34	$0.41
Hot-air damper.	.19	.19	.21	.22	.24	.25	.26	.26	.27	.28	.28	.32
Furnace collars.	.18	.18	.21	.24	.27	.30	.36	.36	.38	.40	.40	.50
Tin elbows.....	.18	.20	.22	.26	.29	.35	.40	.50	.59	.66	.74	.81

The cost of *registers* may be estimated as follows:

Items in Cost	Size of Registers (inches)									
	6×10	7×10	8×10	8×12	9×12	10×14	12×15	12×16	14×18	16×20
Black register.....	$0.78	$0.83	$0.83	$0.96	$1.06	$1.71	$2.22	$2.73	$4.05	$5.53
Slate stone.....	.45	.50	.52	.59	.74	.83	1.10	1.19	1.80	2.91
Register box.....	.20	.24	.24	.26	.30	.31	.35	.42	.57	.72
Netting.....	.05	.05	.06	.06	.07	.07	.08	.08	.10	.12
Total.....	$1.48	$1.62	$1.65	$1.87	$2.17	$2.92	$3.75	$4.42	$6.52	$9.28

Galvanized *smoke pipe* will cost 12 cents per pound and weighs per linear foot as follows:

Size No.	Size of Pipe (inches)										
	4	5	6	7	8	9	10	11	12	13	14
22	1⅛ lb.	2⅛ lb.	2⅜ lb.	3 lb.	3⅜ lb.	3¾ lb.	4⅛ lb.	4½ lb.	5 lb.	5½ lb.	5¾ lb.
24	1½ lb.	1⅝ lb.	1⅞ lb.	2⅛ lb.	2⅓ lb.	2¾ lb.	3 lb.	3⅜ lb.	3⅝ lb.	3⅞ lb.	4¼ lb.

Galvanized *elbows* weigh and cost as follows:

Size of Elbow (inches)	Weight (pounds)	Cost
4	1	$0.26
4½	1¼	.27
5	1½	.29
5½	1¾	.30
6	2¼	.31
7	2¾	.32
8	3¼	.36

The cost of *tin* for sheets of various sizes and weights is as follows:

Weight	Size (inches)	Price (per foot)
DC	12½×17	$0.05
IX	14 ×20	.07
IXX	14 ×20	.08
IX	20 ×23	.12
IX	20 ×26	.13
IX	20 ×29½	.16
IX	20 ×32½	.17

Miscellaneous Cost Data for Installation of Hot-Air Heating

Galvanized sheet iron, per pound	$0.06
Common sheet iron, per pound	.04
Wrought iron, per pound	.04
Galvanized piping, per pound	.12
Galvanized cold-air box, per pound	.12
Galvanized furnace shields, per square foot	.10
Register box netting, per square foot	.05
Asbestos paper at 1½ pounds per square yard	.05

Miscellaneous Rules for Installation of Hot-Air Heating

Figure the cold-air supply as three-quarters combined area of piping.

Register grilles take up one-third of area of register.

Locate registers nearest convenient point to furnace, inside part of room preferred.

Locate the furnace so that all pipes will be as nearly equal in length as possible.

Estimate pipes by linear foot, but elbows and dampers separately, also registers with boxes and borders.

Allow from $1.25 to $1.75 for flange connection of cold-air box to furnace casing.

Cover all risers with asbestos paper in partitions.

Hot-Water and Steam Heating

In estimating for heating with hot water, all pipes and fittings must be taken off and listed, all standard radiators priced by the square foot of radiation, and special radiators, tanks, valves, hangers, etc., listed separately.

Radiators are listed in the trade catalogs, together with the number of square feet in each section. These prices are subject to varying discounts which can be obtained of the manufacturers.

The amount of radiation necessary for each room depends upon so many varying conditions that all rules are in a way approximate. Certain formulas may be used, which will give good results in ordinary cases, but just what allowances are necessary must be determined by the heating engineer. The same is true of making the estimates of hot water or steam and the contractor should in all cases have the job figured by an expert.

In ordinary cases the amount of radiation necessary for *steam* heating may be estimated from the cubic contents of the rooms to be heated according to the following rule:

One Square Foot of Radiation Heats	Dwellings (cu. ft.)	Halls, Stores, Etc. (cu. ft.)	Churches and Auditoriums (cu. ft.)
By direct radiation			
On first floor	35 to 60	75 to 100	125 to 200
On upper floors	50 to 80	.....	.....
By indirect radiation			
On first floor	25 to 40	50 to 70	80 to 135
On upper floors	40 to 50	.....	.....

The amount of radiation necessary for *hot-water* heating is estimated by similar rules.

One Square Foot of Radiation Heats	Dwellings (cu. ft.)	Halls, Stores, Etc. (cu. ft.)	Churches and Auditoriums (cu. ft.)
By direct radiation			
On first floor	15 to 25	30 to 45	50 to 85
On upper floors	25 to 40	.....	.....
By indirect radiation			
On first floor	17 to 40	45 to 65	80 to 125
On upper floors	25 to 35	.....	.....

Having determined the amount of radiation, piping, and fittings, the amount of labor may be obtained by adding about 20 per cent to the cost of materials.

Cost of Pipes and Fittings. Soil pipes should be estimated by the linear foot, $\frac{3}{4}$ pound of lead for every inch in diameter of the pipe being allowed in each joint.

TABLE IV

Capacity of Cisterns

(In Gallons, for Each Foot in Depth)

Diameter* (feet)	Capacity (gallons)	Diameter (feet)	Capacity (gallons)
2.0	23.5	9.0	475.87
2.5	36.7	9.5	553.67
3.0	52.9	10.0	587.5
3.5	71.96	11.0	710.9
4.0	94.02	12.0	846.4
4.5	119.0	13.0	992.9
5.0	146.8	14.0	1151.5
5.5	177.7	15.0	1321.9
6.0	211.6	20.0	2350.0
6.5	248.22	25.0	3570.7
7.0	287.84	30.0	5287.7
7.5	330.48	35.0	7189.0
8.0	376.00	40.0	9367.2
8.5	424.44	45.0	11893.2

*For tanks that taper take diameter four-tenths from large end.

From the dealers can be obtained list prices of pipe and fittings, which are subject to discount; these vary from time to time, but the following are approximately correct:

4-inch extra heavy soil pipe, per foot	$0.36
3-inch extra heavy soil pipe, per foot	.27
2-inch extra heavy soil pipe, per foot	.18
For fittings add 35 per cent	
4-inch running trap	2.75
4-inch brass ferrule cleanout	1.07
4-inch lead bend	1.83
4-inch brass ferrule	1.00
2-inch brass ferrule	.54
Solder, per pound	.40

Below are listed the prices of various materials used in the installation of water.

40-gal. galvanized boiler and stand	$18.00
1-inch brass pipe, per foot	.88
1-inch galvanized pipe, per foot	.15
¾-inch galvanized pipe, per foot	.10
½-inch galvanized pipe, per foot	.08
1-inch stop and waste cock	1.78
¾-inch stop and waste cock	1.20
½-inch stop and waste cock	1.07
Sill cock	1.67
For fittings, add 30 per cent	

The more important water measurements with which the estimator should be familiar are given here. In Table IV are given the capacities of cisterns of different diameters.

1 cu. ft. measures 7.48 gal. = 29.92 qt.
1 cu. ft. weighs 62.321 lb. = 997 oz.
1 cu. yd. weighs 1692 lb.
1 gal. measures 231 cu. in.
1 gal. weighs $8\frac{1}{3}$ lb.
1 ft. cylinder weighs 49.1 lb.
1 in. cylinder weighs 0.028 lb.
1 bbl. contains $31\frac{1}{2}$ gal.
No. of bbl. = contents in cu. ft. $\times$ 0.2375
No. of gal. in ft. of pipe = (diameter in in.)$^2 \times$ 0.04
Pressure per sq. in. = depth in ft. $\times$ 0.433
Pressure of 1 lb. per sq. in. given by column, 27.72 in. in depth
Pressure of 15 lb. per sq. in. (atmospheric pressure) given by column, 34 in. in depth
Head of water = pressure in lb. per sq. in. $\times$ 2.31
Supply for one person per day 15 gal.
Actual use per person each day from 6 to 12 gal.

HEATING

FURNACE—		
1 No. 28 Crawford furnace (28-in. firepot)	$138.00	
22 ft. 8-in. galvanized iron smoke pipe, 55 lb. at $0.12	6.60	$144.60
REGISTERS—		
1 14×18-in. register, stone, box, and netting	$6.52	
4 9×12-in. registers, stone, box, and netting, at $2.17	8.68	
4 8×10-in. registers, stone, box, and netting, at $1.65	6.60	
4 7×10-in. registers, stone, box, and netting, at $1.62	6.48	28.28
PIPING, including dampers, collars, and elbows—		
12 ft. 14-in. tin pipe, at $0.29	$ 3.48	
64 ft. 9-in. tin pipe, at $0.17	10.88	
278 ft. 7-in. tin pipe, at $0.14	38.92	53.28
COVERING FOR RISERS (6 lb. asbestos paper per pipe)—		
5 risers, 30 lb. at $0.05		1.50
PLASTERING RINGS IN CELLAR—		
For 13 pipes at $0.25 each		3.25
Carried forward		$230.91

Brought forward		$230.91
OFFICE EXPENSE AND PROFIT		57.73
LABOR—		
Measuring and laying out risers, man, 1 day	$ 5.20	
Erecting risers, man 2 days; helper, 1 day.	13.20	
Laying out and erecting cellar pipes and furnace, man, 3 days; helper, 2 days	21.20	
Finishing, man, 1 day	5.20	
Carting and expenses	10.00	54.80
Total cost of heating apparatus		$343.44

PLUMBING

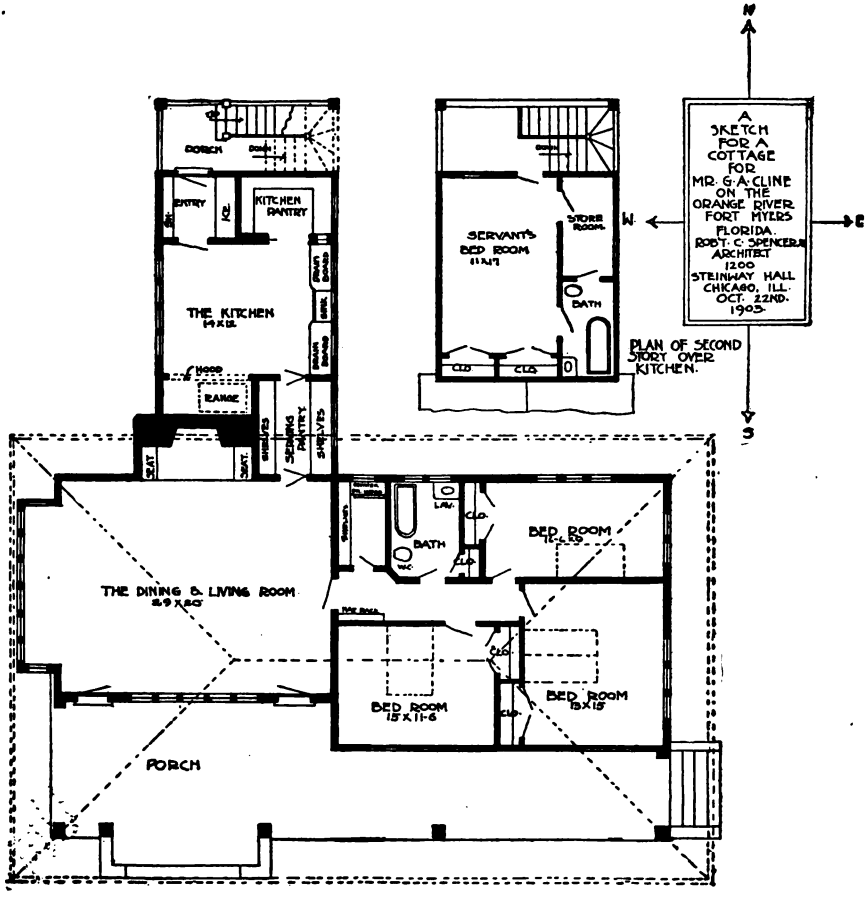
WASTE AND SOIL PIPES—		
2 4-in. lead bends at $3.16	$6.32	
2 4-in. sleeves at $1.00	2.00	
5 2-in. sleeves at $0.54	2.70	
2 3×2-in. sleeves at $0.80	1.60	
1 1½-in. Pemberton trap	8.00	
30 lb. solder, wiping, at $0.35	10.50	
2 trap plugs at $0.65	1.30	
2 6-in. traps at $2.14	4.28	
1 6-in. cesspool	2.12	
4 1½-inch solder nipples at $0.40	1.60	
1 4-in. roof flashing	1.82	
Soil pipe	58.00	
15 ft. 1½-in. lead pipe, No. 55	5.88	
50 ft. 2-in. iron pipe 40 ft. 1½-in. iron pipe	10.87	
Soil fittings, ⅓ cost of pipe	19.35	
Cast-iron fittings, ⅕ cost of iron pipe	2.18	138.52
MISCELLANEOUS FITTINGS—		
3 4-in. brass C. O.	$ 2.90	
1 5-in. brass C. O.	1.58	
Refrigerator waste	15.15	
Local vents	14.60	
1 ball cock	1.52	
2 sill cocks	3.04	
Tank overflow	7.85	
4¾-in. S. & W. cocks	3.93	
1 boiler valve and chain	.76	51.33
Carried forward		$189.85

Brought forward		$189.85
25 lb. tinned copper, at $0.42½	$10.69	
6 3-part hangers, brass	9.44	
2 ¾-in. hose bibs	3.00	
3 ¾-inch plain bibs	4.00	
Street connections	62.50	
1 lb. putty	.06	
2 lb. grafting wax	.65	
Calking lead, 380 lb.	32.25	
Oakum	1.95	124.54
FIXTURES—		
1 36×24×8-in. sink, 12-in. back	$14.00	
1 24×14-in. pantry sink	17.50	
1 pair pantry cocks	4.40	
2 24×48-in. trays, 12-in. back	17.50	
1 5-ft. bathtub, complete	49.70	
1 lavatory, complete	30.00	
1 water closet, complete	55.00	
1 40-gallon boiler	23.00	
1 40-gallon boiler stand	1.00	
12 lb. fine solder	4.65	
Clamps and hooks	3.30	
Tinned tacks	.15	
Fuel	2.38	222.58
SUPPLIES AND LABOR—		
126 ft. ¾-in. galv. water pipe	$ 9.16	
22 ft. ½-in. galv. water pipe	1.25	
Fittings	2.06	
74 ft. ¾-in. brass $34.40		
56 ft. ½-in. brass 24.30	58.70	
Fittings	9.85	
Painting iron pipes	10.00	
Stop cocks	4.30	
Sink and tray legs	5.78	
Lead, oil, etc	.80	
Clamping brass and screws	.30	
Cartage and fares	6.00	
Labor, 40 days, at $6.00	240.00	348.20
		$885.17
PROFIT, 10 per cent		88.52
Total cost of plumbing		$973.69

FLORIDA BUNGALOW.

R. C. Spencer, Jr., Architect, Chicago, Ill.

Outside Walls Rough Shiplap, Stained.



GROUND-FLOOR AND SECOND-STORY PLANS FOR FLORIDA BUNGALOW.

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CONTRACTS AND SPECIFICATIONS

In order to build intelligently and with profit, it is essential after the scheme has been developed on the drawings—that the materials and their qualities be so selected and so designated that there can be no misunderstanding relative thereto, on the part of either the owner or the builder, and that only such materials be required as the former is prepared to pay for.

INTRODUCTION

THE SPECIFICATION AND ITS FUNCTION

Essential Characteristics. The province of a specification is to supplement the drawings, setting forth those points in the proposed work which cannot be readily expressed by diagram and figures. It may therefore be said that its principal object is to define the general conditions under which the work is to be done, and to describe the quality of the materials to be used. In other words, a specification is a statement of the conditions under which the building is to be constructed, and of the items necessary therefor which are not indicated on the contract drawings.

The specification also presents the general conditions under which the work indicated by the drawings is to be executed. It stipulates the kind and quality of labor and materials desired, and contains all the written instructions and descriptions that may be needed to indicate fully to the bidders just what must be furnished.

Clearness. The completeness and clearness of the specification materially govern the amounts of the bids, and also regulate the amount of extra charges brought in by the contractor at the final settlement; a simple description, therefore, giving as briefly as possible the correct idea to the bidder, is likely to achieve a better result than a long treatise on what is recognized as good workmanship and material by any workman capable of undertaking the contract at all.

Quality and Kind of Materials. As a general rule the specification should give the quality and kind of material to be used, and the method of workmanship, leaving the quantities and sizes to be obtained from the plans. This method, if carefully followed, simplifies the checking-up in completing the plans. Changes in quantities and dimensions can be made on the plans, while changes in material are looked for in the specification.

Notes on Drawings. Specifications are sometimes written in the form of notes on the drawings; but these easily become separated, so that the specification might not be considered for every part of the work on which it would have a bearing. Moreover, as there is not usually room on the drawings for the necessary detail, they never can be as complete as a written description, and at the same time they tend to lead the contractor to neglect the complete specifications. On the other hand, notes on the drawings have a certain advantage in being directly before the contractor. They can be easily and permanently put on when making the drawings, and they show the exact location of the materials mentioned.

General Comments on Wording. *Clear and Exact Language.* Specifications must be written in language perfectly intelligible to all persons connected with the work; special care must be exercised in this, since the specifications, together with the contract drawings, form the basis of the final agreement or bargain between the owner of the proposed building and the builder, this agreement being called the *contract.*

The building to be erected is described by the architect in two ways—namely, by *drawings* and by a *written description,* the specification. The same experience and ability that enable him to make the drawings, will be required in formulating the written statements necessary to express what cannot be fully shown in the design. The importance of the specification is shown in the fact that in case of discrepancy it takes precedence over the drawings.

The diction employed, should, therefore, be carefully considered, so that the specification will be a continuous description of the matter, dealing fully with each subject or each part of the work in proper sequence, and, avoiding all reiteration of requirements either in whole or in part. Short sentences referring first to one

subject and then to another, and of doubtful connection, should never be allowed.

Terms Used in Grading Material. Words should be used in their most common meaning, and if an expression indicates only a trade term for a locality, it should be so stated. "First quality" as a trade term, for example, may not mean the best in the market; "Extra No. 1" shingles are not so good as "Extra"; "6-cut" stonework may show many stones which would not appear if "Good 6-cut" were called for. If the architect is not fully informed on these points, he should study more carefully the grades of materials being put into buildings, and how they appear in structures that have stood for some time. Visits to supply houses, mills, shops, and stoneyards, will repay the time spent.

Such expressions as "best", "proper", "sufficient", etc., are capable of being interpreted in very different ways, according to the point of view of a good or a poor workman.

Accuracy of Statement. Generally speaking, adjectives and adverbs and all general description should be dispensed with. The requirement that work shall be finished "in the best possible manner" means very little. A reasonable interpretation of "best work" for a house costing $1,500, would be entirely unsuitable for a house costing $15,000; and as all through the scale the meaning varies, it will be evident that the contractor, influenced by his intent to make a profit, and the owner, influenced by his desire to get his money's worth, will have widely separated views as to what the "best" is. The architect, in attempting to decide the question, is likely to get the ill-will of both.

Each requirement should be so carefully written that there can be only one interpretation, with absolutely no doubt as to its true intent. If the specifier hopes to get better work through some hidden meaning in the specification, he is doomed to disappointment; for the more expensive interpretation will be used by the contractor in making his bid, but later, when the work is required, he may plead that, on account of the uncertainty of meaning, he should not be required to do the work the more expensive way without extra compensation. Make the specification fair and honest, for it is the basis on which the architect will stand as arbitrator during the progress of the work.

It should be remembered that it is the province of the workmen to comprehend and not to originate; and so the statement of what is to be constructed should be made very clear, leaving nothing to the imagination of the contractor. A statement in the specification of what could be better shown on the drawings is likely to be poorly comprehended by the builders; on the other hand, the owner of the building will be wont to think more of the specification, since he can understand this more clearly than he can the drawings. There should be nothing, however, in the specification, or in any part of the work, to discourage originality, personal interest, and the exercise of judgment on the part of the workmen.

Province of Specification. Before a specification is begun, its limits are fixed by the drawings; on them the scheme is illustrated fully, the material indicated in a general way, and all sizes shown. Two tasks are the imperative duty of the specification writer:

(1) To acquaint himself most carefully with all that is illustrated by the drawings;

(2) To determine all that is not given in the drawings.

Having settled in his mind the second point, he has the province and the limits of his work before him; for, as above stated, it is the province of the specification to set forth those points which cannot be explained by the drawings. A most careful study of the drawings, therefore, is necessary, in order to learn every point in the proposed scheme which they do *not* cover—points which *must* be covered in the specification.

To attempt to emphasize requirements already fully shown in the drawings, by calling attention to them again in the specification, adds nothing in the way of obligation, and has the effect of casting doubt on those requirements which are not thus doubly set forth.

A careful consideration, then, of the province of the specification will show that its functions are to define the relations between the different parties, the conditions under which the work is to be done, and the materials used in execution. These are the points which have everything to do with the cost of the work. In building, as in most other items, the form and shape have less to do with the cost than have the conditions under which the work is done and the materials required therefor.

As Relates to Contractor. Specifications should never impose conditions which can involve the contractor in any unnecessary trouble or expense. They should aim so to modify all conditions that the contractor will feel others are co-operating with him to produce the desired result without unnecessary expense or inconvenience. The result desired should always be made perfectly clear and apparent in the wording of the specifications; the means of obtaining that result should, except in rare cases, be left to the judgment of the contractor, who alone is responsible for such result.

Sometimes it is imagined that, unless the conditions are set forth with some degree of harshness, the owner will feel that sufficient protection to his interests has not been provided; but, before the completion of the work, he will probably realize, from the smoothness with which the work progresses, that the tact of his architect has saved him much annoyance and a considerable sum of money.

As Relates to Architect. The writer of the specification must clearly bear in mind, throughout his entire work, that the architect is to occupy a unique position in carrying out the work—a position which in almost no other line is occupied by one individual. The architect is the confidential professional adviser of his patron; and also, as the work progresses, he is to be the unbiased arbitrator, often between opposing interests, one of which is that of his patron or employer. The office of arbitrator is difficult, and one which it is generally impossible to occupy at all times to the satisfaction of both parties; and as the unconscious influence of the patron's interests is very likely to warp the judgment of the architect in making interpretations which must govern, it is very necessary that in the specification all matters be stated so clearly that differences of interpretation will seldom occur, and that when they do occur the specification will give the architect ample standing room, so that his judgment may be accepted without either party feeling wronged.

"Standard specifications", which require "standard materials", put in by "standard methods", have done their part most fully to discourage owners, contractors, and, finally, architects. The same judgment used in buying supplies of life that will satisfy require-

ments, should be used in buying building material; and success in buying depends on knowing how to buy.

Parties Concerned. *Owner.* The owner is the autocrat; his wishes are to govern, and unless his interest can be thoroughly aroused, the transaction will probably end unsatisfactorily. There is no person so hard to serve as one who, while feeling it necessary to build, has no interest in the process. The work, when done, will never be quite what he thought it would be, and he will never be satisfied. The interest of the owner should, therefore, be enlisted concerning as many details of materials as possible, and the reason for using one and not another. His questions will at first be trying. Possibly the first query will be: What will be the increase in cost of a brick or stone-faced house over a wood house?—and no amount of argument or explanation will convince him that no definite ratio exists. But the question can be used as an excuse to discuss the different qualities of brick, or the kinds of stone which he prefers, and soon technical knowledge of these materials will awaken an interest and call out more rational questions. This discussion will reveal the kinds of materials which will be satisfactory to the owner and an estimate quickly made by the architect will answer the question.

It is the right of the owner to understand all the differences in quality of materials, and why each kind is to be used. If he does not, he will probably be much annoyed by the wiseacres, who are sure to criticise everything delivered on the site, and the end will probably be severe criticism of the architect, who "did not know enough to specify the best." It will rarely occur to the owner, that, had the "best" been specified, it would have carried his building well into the hands of the mortgagee. The owner's interest if once aroused, will lead to a co-operation with the architect and the contractor, which will encourage the owner to "give and take" in minor matters, to the mutual advantage of himself and the contractor.

It is, further, the owner's right to have freaks and notions; and, after a careful presentation of the case, his ideas as to materials, though they may be decidedly different from those of his architect, should be respected, and the material incorporated as dictated by him. Herein is the opportunity for the architect to use his best

technical knowledge, and so to meet the conditions that in spite of them the result will be satisfactory. The architect who says that he carried out the dictations of the owner and is not responsible for the result, is likely to lose a patron and possibly to make an enemy.

Contractor. As a general thing, the only object the contractor has in mind in taking the work is the pecuniary profit to himself in the transaction. It is rarely that satisfactory results can be obtained from a man who is losing money; generally he so manages that the owner is as great a loser, and the architect is blamed for the losses of both.

While the contractor is under obligations, after taking the contract, to carry out the work "as directed", it is well to remember that his assumption of the contract was a purely voluntary act, and that he was under no obligation to take it. It is his right to know, before he puts in his bid, just what he is expected to furnish and to do, not to be left to furnish what, in the judgment of someone not interested in him, are materials of "best quality" or "good quality." Nothing will so much tend to draw from the contractor the best results, as to sense a feeling of co-operation on the part of both the owner and the architect.

Specification Writer. The central figure in this transaction is the specification writer. His tact must arrange the conditions under which the work is to be done; his technical knowledge must supply the data, and set forth in clear, explicit language, the description of the material which the contractor is to furnish and the owner is to accept. He is to be the arbitrator when any question arises affecting the interests of both in conflicting ways, and for his own comfort the arbitration must be such that both sides will see its full justice. In order that the necessity for arbitration shall present itself as seldom as possible, it is essential that all the conditions and questions liable to cause misunderstanding be fully studied and settled in the specification. It is the duty of the superintendent to see that the contractor follows out the requirements of the specification, but it is unfortunate to have the specification so loosely written that the requirements are ambiguous, or at least not explicit, and the contractor is made to feel that he is distrusted, or that he is obliged to furnish materials or labor at a loss under an arbitrary

decision, which, had the detail of the specification been more clearly given he would have avoided.

Particular attention is called to the following paragraph, as the advice contained therein is of the utmost value:

The specification writer must be a man of tact and technical knowledge. It is outside the scope of this paper to discuss the former quality, except in a most general way, but an effort will be made so to treat the technical side that the student can develop lines of thought that will enable him, whenever questions arise, to attack them from such points as will gain for him the necessary inside information; in no sense is it the intent of this paper to set up such matter as will serve as models and forms to be applied to miscellaneous conditions. The training of the specification writer should be such as to accustom him to think in building material; *and when the habit is formed, the student, in passing from day to day, structures completed or in course of construction, will constantly find himself reasoning as to the use of various materials. This is technical education. No school, no matter how long or how thorough its course, will cover all the points to be decided in the first modern specification. All the training any school can give is to teach a man to think out the solution of his first and each succeeding commission along sound lines. This is the character of work which rouses enthusiasm in the worker and without which the work will amount to little.*

POINTS OF EMPHASIS IN SPECIFICATION WRITING

Preliminary Work. It is advisable for the specification writer to block out a *memorandum specification,* indicating very generally the points which will be completely covered in the finished copy, and to do this at the time the architect is making the preliminary sketches, which indicate the scheme to be followed later in the contract drawings. With this preliminary specification a close estimate of cost can be made, and the modifications incorporated which are necessary to bring the cost of the work within the stipulated sum. In the final writing, however, this memorandum should be used only for reference, as an effort to copy any part of it bodily into the completed work is likely to introduce matter not desired, or to cause the omission of essential matter not considered at the time the memorandum was made.

There are certain data that it is advisable to obtain before writing

the specification, such as the information obtained from test borings to determine the condition of the soil, references as to the location of sewers and water-supply pipes, etc.

Bill of Quantities. It is sometimes held that the specifications should be considered as a sort of index of all the labor and materials required in the structure, and that any items not mentioned in this index cannot be required. This feature, however, is the province of the bill of quantities which in this country is prepared by the contractor for his own use, and not by the architect. The contractor makes up the bill of quantities from the drawings and specifications which together show the shape, size, and quality of materials, but which should never attempt to state the quantity in detail; for if an attempt is made to designate where materials are to go, and if for any reason every single point is not covered in such designation in the specifications, the contractor may seize upon the omission as an excuse for an "extra." There is a growing sentiment, however, in favor of the employment of a *quantity surveyor,* whose duty it is to make up from the architect's drawings and specifications a bill of quantities, to be used by the competing bidders, and to be later the basis of the contract or agreement between the successful bidder and the owner.

Form of Publication of Specifications. Specifications are ordinarily typewritten, and several copies are usually made—one copy for the owner, from one to three for the contractor, one office copy, and extra copies which may be used in securing estimates, supplied to the Inspection of Buildings' Department, etc. If many copies are required, the specifications are sometimes lithographed, printed, or mimeographed. It is the custom in some offices to print in typewritten form, or to mimeograph, the general conditions only, which are the same in different specifications; but it is better to have the general conditions written in the same form as the general specifications, for if they are not the contractors are likely to overlook them and to neglect the directions therein stated.

Marginal Sketches. Sometimes sketches are made in the margin of the specification to indicate the use of materials or to show required details. This can be done easily if the specifications are printed or lithographed, but under the present system of duplicating by typewriting, it is difficult. This sort of information can

be shown more completely on the regular drawings, which can be reproduced in sufficient quantities to explain every item.

Preliminary Estimates. Preliminary estimates are generally obtained from some "reliable contractor," who is called in before the specification is complete, to estimate the relative cost of certain parts of the building where there is doubt as to which of two methods or materials to use.

It is better, however, for the architect to become familiar with the prices of different items, so that he can estimate for himself the cost of various schemes, unless the owner has settled on one particular contractor to whom the work is to be let. When the "reliable contractor" is called in, he appreciates fully that the time he puts on the estimate will be in the nature of gratuitous services, or nearly so, and therefore careful figures are not made, and often the architect and owner are both misled.

Classification of Work of Different Trades. The opening description of the work should be straightforward, clear, and concise. The specification should be carefully classified according to the different trades, so that each sub-contractor and the estimator of every small shop may find the work he is to do definitely indicated. It is easy for a general contractor to unite sub-contracts and let several to one firm, but very difficult to subdivide a specification where trades are not differentiated. This should not lead the architect, however, to separate work among different trades, if safety, warranty, or promptness requires that certain parts of the work shall all be under the control of one contractor, as, for example, the roofer.

Each item describes the class of material to be used and the kind of labor to be employed. The number of pieces and the dimensions are left to the plans; though when, however, the plans are incomplete on account of the small scale, the quantities and sizes must be given fully and completely in the specifications.

The usual method of arranging a specification is to classify the items under each building trade, and then to subdivide the building trades as much as possible. Commence with the work to be done on the foundation of the building and carry the description up through the building to the roof in the order of construction. In this way there is less danger of omissions. Sometimes it is advisable to de-

scribe a certain part entirely under the trade that would have general charge of it. For example, an iron staircase would be described under "Iron Work," and the description would include a wooden handrail. Metal flashings, it is often specified, are to be furnished by the carpenter, mason, or plumber for use in connection with their work, though frequently these are provided by the metal worker and set by the carpenter, mason, or plumber.

It should be stated and understood that every contractor is to report any defect or discrepancy, as soon as observed, to the architect, and to lend his personal interest and attention to the best possible execution of the whole work.

Alterations in Specifications. The sets of specifications as well as the drawings which they accompany, must be kept unchanged, for reference, both when the estimates are received and when the contract is signed. Later changes must be shown by other drawings and by "addenda" to the original specifications. Interlineations in a specification should not be made if there is time for rewriting. If made at the last moment, they should be signed individually at the time of signing the contract. All changes introduced after the specification is completed and the contract let, which involve extra charges, should have each a complete descriptive specification written, referring to the general specification.

Arrangement for Reference. In writing out the specification, it is advisable and usual on public work to number every clause under the different trades in order. These numbers will be found very useful for reference and comparison during the work. An index may be placed at the beginning of the specification.

Inclusion of Indirect Items. There are many indirect items which should be fully covered by the specifications—for example, the requirement that the contractor shall take care of certain minor points, such as clearing out rubbish, covering the windows, and heating the building while the plaster is drying, putting up staging, etc. Even when there is a general contractor for a building—which would relieve both architect and owner of any direct responsibility —it saves much discussion between the sub-contractors if such points as these are included in the specification.

Attention to Public Regulations. Due consideration must also be given to the various state and municipal regulations which are

enforced for the preservation of public health and safety; and also to insurance regulations which apply primarily to the prevention of property loss by disaster of any kind.

These regulations are directed principally toward securing sufficient strength and stability to prevent collapse of construction, sufficient protection against fire from within or without, adequate ventilation and sanitation, and have regard, besides, for measures of public welfare such as open areas, the protection of property values, and the improvement of civic beauty.

Where there are definitely stated requirements in state or municipal building laws, use the same wording or expressions in the specification. The provisions in the laws are the result of long study and practical experience, and often the difference of a single word will confuse or obscure the meaning to the contractors. The specifications may be abbreviated by referring directly to the building laws, and omitting what is there clearly stated.

Restriction on Architect's Powers. While every specification should require that the work as a whole and in all details shall be carried out to the satisfaction of the architect, such requirement must carry with it the full understanding that the architect shall be satisfied when the contractor has furnished what the clear meaning of the drawings and specification calls for, and under no circumstances shall the architect, under the excuse that what has been furnished is not satisfactory to him, demand other than that which is required by the drawings and specifications.

Use of Warranty Clauses. It is often desirable to stipulate that certain portions of the work are warranted to exercise their functions properly when completed, and for a certain period of time thereafter. For example, the heating specification may stipulate that the apparatus is to maintain a temperature of 70 degrees when that of the outside is at zero or 30 degrees below; or it may be that the roof is to be warranted to remain waterproof for a certain length of time. Such warranty clauses should be sparingly used, for in case of a defect in the portion warranted, it is generally as expensive to get the person who installed the defective portion to remedy it, as to get the work done over by another party, and the delays incident are annoying in the extreme. When a warranty clause is used, it is generally made an excuse for constantly chang-

ing the work from that specified, under the plea that, if carried out in accord with the contract, the work cannot be warranted. Such changes are always in favor of poorer work. It is generally better for the architect to know just what materials will do the work, to see that such are installed, and to leave the warranty clause out.

Specification for Particular Brands. Specifying a particular make or brand of material is likely to carry the impression that the writer's knowledge is limited or that he is unduly influenced in favor of the article specified. If a particular appliance is required, it is well to except it from the contract, and say that the owner "will furnish, ———————— delivered on the site, which the contractor is to set in place and connect," etc.

Employment of Consulting Experts. In important work, specifications on electric wiring, heating, plumbing, ventilation, etc., are frequently prepared by consulting engineers employed by the owner to arrange these points under the direction of the architect. In this case the engineers prepare the specifications, which can be included in the architect's other specifications, and any questions that may come up during the progress of the work should be referred to the consulting engineer by the architect before a change is made. The employment of consulting experts is common in the erection of high buildings, where engineers are frequently engaged to lay out the steel construction.

But when the services of specialists in any line are required, it should in all cases be understood that the general scheme for the work is not to be altered, and that the engineer is to adapt his portion of the work to the general plan, and not to insist on modifying the general plan to suit any particular methods or appliances he may desire to use.

Specification as to Payment and Time of Completion. In a building operation, four questions always arise:

(1) **What is to be done?**
(2) **How is it to be done?**
(3) **When is it to be completed?**
(4) **What is to be the manner of payment?**

The first two questions are answered by the plans and specifications. Although the last two are finally stated in the contract, it

is necessary that some reference should be made to them in the specification, for the information of the bidders.

The period for completion may be stated in terms of months and days after the signing of the contract.

Payments on the contract may be made by one of four methods:

(1) Stated sum
(2) Cost plus a percentage
(3) Cost plus a percentage with guaranteed limit
(4) Cost plus a fixed sum

The first is the usual way in contracting work.

Full information relative to the method of payment which the owner prefers and intends to incorporate in the contract, should be set forth in the specification, as this is a matter which will have a marked influence on bidders.

If "payment by stated sum" is agreed upon, then, unless the payments can be arranged so that the owner supplies money for the material and labor at frequent intervals, it follows that the contractor has to use considerable of his own capital or credit to carry the work along. For this he must be paid; and, therefore, as the owner generally has the funds prior to beginning work, it is advisable to state in the specification such dates and percentage of payments as will permit the contractor to carry on the work with a minimum charge for the use of his own capital or credit.

SPECIFICATION WRITER'S METHODS OF WORK

Outlining Main Divisions of Work. The completeness and clearness—and therefore the usefulness—of a specification, depend on its systematic arrangement. The first thing to do, therefore, is to prepare a skeleton or outline of what is later to be the finished form. This should consist, in the first place, of a list of the different *general* branches of the work. Then, under each of these general heads should be set a list of sub-heads; but it is not good policy to attempt to cover every point before beginning the writing of the specification proper, as, in writing, items will constantly occur to the writer in connection with what has already been written. After this skeleton has been prepared, the major part of the work is done, as the filling-in and detailing of requirements under each heading is a comparatively simple operation.

Use of Card Catalogues. On smaller work, where the Architect is both designer and specification writer, the job will be, or should be, so in mind that no assistance is required in arranging this skeleton; but in larger offices, where generally the first time the writer sees the drawings is when he begins consideration of the specifications, it is very desirable—in fact necessary—for him to have some reminder of the items which are to be considered. These reminders may be in the form of the catalogue cards which are used in some large offices to list specification items. Each card contains notes and memoranda relative to one item, and the cards of the file can be easily grouped and re-grouped—using markers or wire clips—to take care of the particular requirements of each contract. With these in hand, the specification writer, although hitherto unacquainted with the drawings, can work intelligently and effectively. As the use of the cards extends, the information accumulated on them becomes very valuable. Items observed from day to day in technical papers or on buildings in course of construction, and facts gleaned from conversation, should be noted on the cards in careful but abbreviated fashion, under the proper headings, and these will recall the details of the case when their assistance will be useful.

Analysis of Task. The drawings, after they have been delivered to the specification writer, should be most carefully studied, for the whole scheme of design, arrangement, use, construction, and decoration must be well in mind. Having obtained a broad, comprehensive impression of the work, the general method of obtaining the results desired, is next to be studied. Considerable time can be spent in this work to advantage. It is a good plan, after what has seemed a sufficient period of study, to sit down, close the eyes, and call to mind the different parts as a whole and in detail. If the scheme then appears clear, and can be followed out understandingly in the mind, without reference to the drawings, then—*and not until then*—is the writer fitted to begin the work. With such preparation he can with surprising rapidity lay out his first line of main heads, and with a similar rapidity, his subheads; when these are completed, the main part of the work is done. Too much stress cannot be laid on the importance of a clear comprehension of the entire scheme, as a whole and in detail, before a word is written.

If the writer fails in this, his specification will be neither clear nor complete, and will be likely to degenerate into a series of disconnected sentences with little or no affinity for those which precede or follow.

Specification Reminder. There is given below a list of headings which cover certain items generally needed, with occasional notes written out to illustrate how other notes can be made when experience furnishes the material. It is especially desirable to call attention in the notes to any particular difficulties in any line of work which may have been previously observed, and the means employed to correct them.

GENERAL CONDITIONS

Division of work
Work to be done
Quality
Materials and labor
Delivery of materials
Contractor
Laying out of work
Engineer
Permits
Building laws
Fences
Office
Vouchers
Inspection
Protection of work
Rubbish
Scaffolding
Defects
Assistance to other contractors
Cutting
Architect
Drawings and specifications
Detail drawings
Charges
Bond
Insurance
Ownership of old material
Water supply
Temporary watercloset
Contingent work
Award
Terms of payment
Changes
Time for completion

MASONRY

Alterations and Shoring

Shoring
Raising
New openings
Piers
New underpinning

Demolition and Removal

Old building
Tearing down
Removing walls
Brick
Old vaults and cisterns
House mover
Ownership of old material
Removal of old material

Excavating and Grading

Location

(If there is much change of level it is advisable to have a surveyor lay out the finished grades.)

Clearing the site
Excavation for cellar
Excavation for areas
Excavation for drains
Excavation for water
Excavation for cesspools
Blasting
Grading

(If possible, have the scheme of grading laid out before beginning to build, in order that the earth excavated from the cellar may, with one handling, be carried to the proper location to carry out the scheme.)

Footings below frost
Shoring
Bracing
Temporary piling
Surplus earth
Saving loam
Trees
Shrubs

Stone Masonry

Lime—Cement—Sand
Non-staining cement
Mortar—Ties
Facing walls
Bed of stone
Bond of stone

Damp-proofing
Coping
Curbing
Concrete floors
Steps
Walks

Cut Stone

Stock—Limestone; sandstone; granite
Finish

Carving
Cleaning

Concrete Construction

Cement—Sand—Aggregate
Mixing

Reinforcing materials
Blocks—Beams—Forms

Brick Laying

Common brick—Sand mold—Pressed; enameled
Lime—Cement—Sand
Bond—Common; English; Flemish
Cutting
Wetting brick
Freezing weather
Bedding window frames
Chimneys—Flue linings

Chimney caps
Chimney bars
Chases
Hollow walls
Boiler setting
Register openings
Rough fireplace openings
Iron doors

Terra Cotta

Partitions
Floors
Furring

Fireproofing
Ornamental terra cotta

Plastering

Grounds
Wood lath
Metal lath
Back plaster
Two-coat work
Three-coat work
Exterior plaster
Pebble dash
Lime and sand mortar
Hair
Patent plaster
Corner beads
Cornices
Relief work

Tile Work—Marble and Slate

Fireplaces
Interior marble work
Mosaic
Terrazzo
Bathroom
Walls—Floors
Plumbing marble

STRUCTURAL STEEL AND IRON

Quality—Cast; wrought
Tests
Bolts
Rivets

ORNAMENTAL IRON AND BRONZE

Cast
Forged
Grilles
Elevator enclosures
Steps
Coal-hole cover
Stable fittings

MISCELLANEOUS IRON

Fire escape
Balconies
Wire guards
Tree guards
Wheel guards

SHEET-METAL WORK

Copper
Lead
Zinc
Gutters
Ventilators
Flashings
Skylights
Cornice work
Eave troughs
Speaking tubes
Ventilation flues
Heat ducts

ROOF

Tar and gravel
Copper
Canvas
Tin
Shingles
Slate
Valley
Flashings
Snow guards

CARPENTER WORK

Framing
Sheathing
Lining
Flooring
Window weights and cord
Exterior finish
Cornice
Closets

Finish lumber
Paper
Doors
Sash
Blinds
Glass
Interior finish—Pine; hardwood; natural; paint
Refrigerators
Mantels
Stairs

HARDWARE

Locks
Knobs
Escutcheons
Sash locks
Sash lifts
Springs
Hooks
Knocker
Hinges
Special hardware for casement windows
House number
Blind fixtures
Screen

PAINTING

Lead
Oil
Shellac
Varnish
Colors
Putty
Whitewash
Number of coats for each material
Finish
Exterior stains
Metal work
Roof
Interior walls
Plumbing pipes

GLASS

Plate—Double-thick; single-thick
Stained—Ribbed; wire
Cleaning
Glazing

HEATING

Laying out work
Cutting, etc.
Foundation
Flue
Furnace
Cold- and hot-air ducts
Registers
Boiler
Piping and hangers
Valves
Heat regulator
Radiators
Tank
Boiler and pipe covering

PLUMBING

Fixtures
Bowls
Closets
Bathtubs
Wash-trays
Sinks
Urinals
Connection with waste pipes
Laundry stove
Hot-water boiler
Water front
Water piping
Shut-off cocks
Soil piping
Branches
Traps
Refrigerator waste
Back-air pipes
Fresh-air inlet

GAS

Pipes	Stove connection
Tests	Gas machine
Outlets	Gas logs

ELECTRIC WORK

General description of scheme	Fixtures
Wire	Switchboard
Conduits	Switches
Outlets	Meter connections

The list given is not intended to be in any sense so complete as to be a sufficient guide to work in *all* buildings. It is inserted to illustrate the scheme often used in offices where the specification writer is somewhat unfamiliar with the work already laid out on the drawings. Practice differs so radically, and the range of building is so wide, that a comprehensive list, covering all the multiplicity of questions that arise in connection with buildings, would be cumbersome. But, following the lines above laid out, each specification writer can rapidly accumulate what he needs in his particular line; and the *operation of seeking* for new items of importance in practice will be a source from which much valuable information and experience will be obtained.

Practice for the Student. Before proceeding, the student should prepare a schedule along the lines suggested above, but specifying under each heading at least double the number of sub-items mentioned.

He should also write a description of the character of work referred to by each heading, these descriptions each to contain approximately one hundred words. Below is given a brief description of the subject of "Heating," which will serve to illustrate the work the student should do:

HEATING

There are five principal methods of heating dwellings—namely, by fireplaces, by stoves, by furnaces, by steam boiler, and by hot-water boiler—all adapted to fuels in common use.

Fireplaces are suitable in mild climates, and to supplement more efficient apparatus in cold climates.

Stoves are the most economical, but are often objectionable fixtures.

Furnaces deliver heated air to the various rooms, and are satisfactory for small buildings.

Steam and hot water supply heat from radiators in each room. Steam responds more readily than hot water to variations in the size of the furnace fire, and should be used, therefore, when quick changes in temperature are desired. It should also be installed in the larger classes of buildings where it can be easily controlled.

Hot water should be used when an even temperature at all times is desired.

Use of Similar Specifications as Basis for Work. New problems are constantly arising which tax the ingenuity of even the experienced architect, and which necessitates new directions. Many building operations have requirements so unusual that any aid except that of general experience will be of little value. As a rule, however, good results will be achieved if the specification writer uses the written or printed specifications prepared previously for work of similar character, or the cards which record the separate items, and makes thereon the necessary changes, giving meanwhile careful and constant attention to the plans, and comparing frequently the plans and specifications. Before the drawings are sent out, the specifications should be carefully checked with the "specification reminder," to discover omissions. In work containing unusual or elaborate detail or intricate alterations, it will be easier to write out a new specification completely than to alter an existing one.

Final Steps in Preparation of Specification. The specification writer generally starts his work with the drawing hung on a wall or screen near by. With the plans closely in mind, he should block out the list of headings, forming a skeleton or general synopsis of the whole. Then he should go through the different trades, checking, writing, and dictating, either following a card catalogue, taking a printed form or standard specification and filling in the blanks, or using an old specification and interlining the changes, which are then copied to form the complete document. Extra care must be taken to cover new and important points that are likely to be insufficiently studied. It will be found rather difficult to make an old form apply to a new building, without the use of too many general terms and "blanket clauses."

Having made a thorough study of the subject, the specification writer may lay out his work under the following headings:

I. GENERAL CONDITIONS
II. EXCAVATING AND GRADING
III. STONEWORK
IV. BRICKWORK
V. LATHING AND PLASTERING
VI. METAL WORK
VII. CARPENTRY
  Framing
  Exterior Finish
  Interior Finish
  Hardware
VIII. PAINTING
IX. GLAZING
X. HEATING
XI. PLUMBING
XII. GASFITTING
XIII. ELECTRIC WIRING

Under each general heading will come many and various subheads. Thus, for instance, under "GENERAL CONDITIONS," will be listed such items as "Material and Labor," "The Contractor," "The Architect," "Drawings and Specifications," "Details," "Time for Completion," etc.; under "EXCAVATION," "Preparation of Site," etc. Every aspect of the work should be included in the complete outline.

SPECIFICATIONS FOR SUBURBAN WORK

The following specification is given to show the method of writing a specification for a particular building. In every case the architect should consider every item necessary for the building and should write out exactly what is desired.

SPECIFICATIONS

FOR A COUNTRY HOUSE TO BE ERECTED FOR

GEORGE A. JONES, ESQ.

AT RIDGEDALE, MISSOURI

Frank A. Bourne, Architect

GENERAL CONDITIONS

Materials and Labor. All materials and labor required for the complete execution of the work are to be of the best quality, unless otherwise provided, and are to be furnished in place by the Contractor. The Contractor is also to furnish all scaffolding, apparatus, etc.

Contractor. Personal superintendence is to be given by the Contractor to the work, and a competent foreman is to be at all times on the work. He is to lay out the work carefully, and shall be held responsible for any mistakes which he, or any one in his employ, or any of his subcontractors, may make.

He is to be responsible, also, for any accidents either to person or property, which may occur in connection with the execution of the work either directly or indirectly, for which otherwise the Owner might suffer.

He is to obtain all permits from the city officials required by ordinances; is to pay all fees for water supply, sewer connections, etc.; and is to follow all the requirements of the building laws, whether incorporated in this specification or not.

He is to be responsible for all materials, whether incorporated in the building or not, until the final acceptance of the work; and any damage there may be from any cause is to be repaired; or, if beyond repair, the damaged portion is to be replaced.

He is to keep the building fully insured; and all policies are to be so drawn that the loss, if any, is to be paid to the Owner as his interest may appear.

He is to provide such fences as may be required to protect adjoining property.

Architect. The Architect shall have charge of the work, and is to exercise such supervision as will enable him to determine whether the true spirit and intent of the drawings and specification is being carried out. If, in the exercise of this function, he finds that any employe of the Contractor is, through incompetence or wilfulness, a detriment to the work, he shall file with the Contractor definite charges; and, upon the filing of such charges, the Contractor shall discontinue the services of such employe in connection with this work.

The Architect shall issue on the third of each month a voucher calling for ninety (90) per cent of the value of labor and material incorporated completely in place in the building on the first of the month, which voucher shall be honored on presentation to the Owner; but this clause will not require the Architect to include in the voucher the value of any material placed in the building which in his opinion does not meet the contract requirements.

The Architect shall be the interpreter of the intent and meaning of the drawings and specification, and his decision shall be final and binding on both Owner and Contractor.

Drawings and Specification. The drawings and specification are to be considered as co-operative; and the material or work called for by one and not indicated or mentioned in the other, is to be furnished and done as though fully treated in both.

If no figures or memoranda are given, drawings are to be accurately followed according to scale; but wherever there are figures or memoranda, these are to be followed instead of the scale, if there is a discrepancy.

Detail drawings shall be furnished of such portions of the work as the Architect may desire to explain more fully; and any work constructed without such drawings (except by permission expressly obtained), or not in accordance with them, must be taken down and replaced at the Contractor's expense.

No changes are to be made without a written order signed by the Architect; and the adjustment, whether allowance or extra expense, is to be made at that time.

Time for Completion. Work is to commence at once, and is to proceed with promptness and despatch.

Work is to be completed and building delivered to Owner six months after date of contract. Times of completion of the different parts are to be as follows, the time allowed in each case to be from date of signing contract.

Foundation ready for sill	1 month
Frame enclosed, chimney completed	2 months
Outside finish on	3 months and 15 days
Plastering	4 months
Interior woodwork	5 months and 15 days
Painter's work and completion	6 months

(Month and day to be inserted in contract and specification for each period mentioned above)

EXCAVATION, GRADING, ETC.

(NOTE TO STUDENT.—For this part of the work it is of advantage to draw a *lot plan*. This should show the system of drainage, which, if not included in the Architect's drawings, is often not very satisfactorily studied or understood. This part of the work, however, often depends on local conditions or customs in different towns, and for that reason is not made a part of the general contract. The drainage and water supply are often taken care of by the city or town authorities, the pipe being carried either to the lot line or to the outside of the building wall. The Architect has to ascertain what the system is, and to write his specification accordingly.

A datum* line (if not already given) should be established by the Engi-

* For convenience in engineering operations, there is established in each locality a *datum line*—that is, a horizontal line passing through a certain fixed

neer's level, at the sidewalk curb. This should be obtained for use in making the sketches and plans, and should be referred to frequently. If the first-floor level is determined in the studies with relation to this datum line—or "bench mark", as it is often called—the location of the building will be much more easily determined. If the lot plan is kept separate from the drawings, it can be contoured to show the different levels; and sections can be drawn on the margin to show the slope of the land. This plan can also be used for locating drainage and water and gas supplies.

The parts of the drawings referring to the excavator's work should be as carefully studied as those relating to any other part of the building operations. If possible, borings should be made on the lot before commencing the drawings, so that the character of the soil can be determined.

A few dollars spent by the Owner for borings on the lot and for a careful survey will be more than repaid by certainty in the excavator's estimate.)

Preparation of Site. The Contractor is to stake out the building, and to erect permanent batter boards at such points that they will not be disturbed during the construction of the foundations.

Clear lot for the building, removing soil and loam from site and 8 feet additional, and stacking it within 40 feet of the building where it may be used for final grading. Remove rubbish; cut down and remove any trees marked as condemned by Owner or Architect, and carefully protect all trees that are to be preserved.

Excavation. Excavate for all work covered by this contract, to at least one foot outside the cellar wall to the depth shown, and no deeper. This includes drains, dry wells and trenches, as well as cellar.

The dry well for refrigerator waste is to be 3 feet in diameter, 6 feet deep, with trench to same 5 feet deep and 8 feet long.

The trench under the cellar wall is to slope to drain cellar. No walls or piers are to start less than 4 feet 6 inches below the surface of ground.

Excavate for water pipe, gas, fresh air ducts, and for drain and cesspool about 40 feet from house. Excavate for piazza piers and for chimney footings.

Grading. After mortar of foundation walls is set, fill with stone and gravel to within 18 inches of finished grade; and after first-floor joists are set, complete filling, tamping every foot in height. Grade to level shown on drawings, so as to turn water away from building, using earth and top soil first removed.

Grade at completion as directed, removing loam where filling is called for, and covering with 12 inches of loam for lawn, and 18 inches depth of loam for shrub planting. For paths, where

point marked zero. Levels above this are marked thus, "+15", "+20", etc., which means that these particular points are 15 feet, 20 feet, etc., above the fixed point. In coast regions, this datum line is often fixed at low-water mark.

All city grades are figured from the datum line; and to establish such a line at a building is to fix a level at the required number of feet above the original. Thus, on the seacoast, the levels may run down to +10 or +18; while in Denver, which is at comparatively high altitude, is a datum line or bench mark + one mile (or +5,280 feet). In such localities it is usual to drop the first two figures and call the bench "+80."

shown, excavate 12 inches deep, fill with gravel made to crown 2 inches.

Care of Lawn. Sod for 2 feet on border of path and lawn, and 3 feet next to building. Lawn is to be leveled, raked clear of stones, and sown with best approved grass seed; it is to be properly watered and cared for until completion and delivery of building. Allow one hundred dollars ($100) for shrubs delivered, and plant same.

STONEWORK

Lime, Cement, and Sand. All lime is to be best quality Rockland or its equal, freshly burned; and all cement is to be first quality Portland. Brands are to be approved by Architect. All sand must be clean and sharp.

Mortar. Except where otherwise specified, the proportions are to be as follows:

Lime mortar—1 part lime to 3 parts sand
"Half-cement" mortar—1 part Portland cement, 1 part lime, 5 parts sand
Lime-Portland cement mortar—1 part Portland cement, 2 parts lime, 4 parts sand
Portland cement mortar—1 part Portland cement to 3 parts sand

Walls. The Contractor is to furnish all materials and to build wall and footings as shown on drawings, of good local stone in irregular courses, the first 12 inches to be laid dry in the trenches, and the remainder below ground to be laid in Portland cement mortar, the whole to be laid to a line on the outside face, and well bonded. The joints are to be thoroughly filled with mortar, and are all to be pointed inside and outside the whole height, holding the trowel so as to weather the pointing on the outside. There shall be at least one through bond stone to every ten square feet of wall.

The underpinning and all stone work above grade are to be laid in "half-cement" mortar, neatly pointed on the exterior with Portland cement mortar colored to match the stone, and to have ruled joints.

Carefully level the walls to receive the sills, and imbed in mortar. Cellar window sills to have wash formed with Portland cement.

Cement Coating. Mortar composed of 1 part Portland cement and 1 part sand, is to be applied to the outside of the wall below grade on the uphill side of building, from bottom to finished grade.

Cut out joints of exterior wall, where exposed above grade, ½ inch deep, and point neatly with Portland cement mortar, as described.

Drainpipe and Cesspool. The drainpipe is to be 5-inch, best glazed earthenware pipe, furnished and laid from cesspool to a point 5 feet outside cellar wall. Joints are to be filled with Portland cement. Connection is to be made by plumber.

Construct at a point about 40 feet from house two cesspools, as shown, one to be 4 feet, 0 inches in diameter, and 8 feet deep, with 8-inch brick walls, thoroughly cemented inside and out and made water-tight. Six feet from same, construct a leaching cesspool, 6 feet in diameter and 8 feet deep, made of loose stone, laid dry.

From iron pipe outside of building, connect house with cesspool by 4-inch Portland stoneware pipe. Also connect the two cesspools with Portland stoneware pipe, as shown.

The cemented cesspool is to have tight iron cover; the leaching cesspool is to have a ventilated iron cover.

Four-inch glazed earthenware pipe is to be furnished and laid from dry wells to one foot above ground, for conductor drains. Set iron pipe furnished by plumber to receive conductors.

Concrete Cellar Floor. Concrete is to be laid in the basement. Level off with coarse gravel; settle thoroughly, and put down 3 inches of concrete, composed, to the thickness of 2 inches, of 1 part Portland cement, 2 parts sand, and 3 parts clean, coarse, sharp gravel, well tamped; cover with 1-inch coat, composed of 1 part Portland cement and 2 parts sand; finish to true and even surface so that cellar will drain dry.

BRICKWORK

Except as otherwise specified, the brickwork is to be laid with hard-burned common brick, carefully selected for exposed work such as facing of chimneys above roof; all must be new, well shaped, and of uniform size. Bricks are to be laid wet in warm, dry weather, and dry in damp or freezing weather. All mortar to be lime-Portland. Joints are to be thoroughly flushed with mortar and well pointed. All outside exposed work is to be washed down after completion.

Chimneys. The chimneys are to be laid in Portland cement mortar. Build in lead counterflashing, at least 2 inches into the mortar joint, and turn down over the roof flashing.

Plaster the exterior of all chimneys where not exposed.

The *chimney caps* are to be of 2-inch blue stone, using only one piece to each chimney; the *flue holes* are to be cut through, and ½-inch smaller each way than the flue below.

All *flues* are to be lined with hard-burned terra cotta, 1 inch thick, set with very close joints filled with Portland cement mortar.

Terra cotta round *thimbles* are to be set for all smoke inlets; and in the ventilation flue, a square opening for a register is to be formed with square, smooth brick.

Fireplaces. Two 2-inch by ½-inch wrought-iron *chimney bars,* to support flat arches, are to be placed above each fireplace, 8 inches longer than opening.

Provide and build into bottom of each chimney one 8-inch by 10-inch cast-iron door and frame and set *clean-outs* to all flues.

Trimmer arches are to be turned for hearths on center of fireplace, and are to be 2 feet wide and of lengths equal to the hearths. Level up with cement to receive hearth.

Run 4- by 8-inch *ash flues* from first story fireplaces to ash pit.

Finished fireplaces are to be formed as shown in detail drawings—face, back, and fire bed of 1½-inch Philadelphia brick, with hearths of red, unglazed kitchen tile, or same as face. They are to have two 2- by ½-inch bars, cast-iron throat, patent damper and slide, and ash dump. After completion, each fireplace is to be kept protected. Samples of brick and tile must be submitted for approval.

Girder Supports. Set brick piers or iron columns in basement where shown, for support of girders, bricks to be laid in Portland cement mortar. If iron columns are used they are to be 4-inch and concrete-filled, with cast-iron caps and base plates.

LATHING AND PLASTERING

Lathing. Lath all walls, ceilings, and partitions (except behind sheathing in kitchen, but including all space behind all other sheathing and wainscots); also all furring, studding, soffits, and the underside of stairs throughout first, second, and third stories; also the laundry, head of stairs to basement, and cellar ceiling (but not where marked "unfinished" on the plans). Good spruce laths are to be used, set ⅜-inch apart and nailed with four nailings to a lath. Break joints every sixth course, and over all door and window openings. All laths to be put on horizontally. Metal lath over heater in basement.

Plastering. Plaster all above-mentioned lathing two coats.

The *rough coat* shall be the best, thoroughly slaked, pure eastern lime; clean, sharp sand; and best, long cattle or goat's hair, mixed in the proportion of 2½ bushels hair to 1 cask lime and 3 barrels sand, to be thoroughly worked and stacked outside of buildings at least ten days before using. Carry first coat to rough floor. All to be well troweled and straightened up with a straightedge.

The *skim coat* shall be sand finish, of white, well-washed sand, 3 parts sand to 1 part white lime putty, floated up with cork floats, and left medium rough; sample to be approved by Architect.

Whitewash. Whitewash all brick or stone work, etc., in basement, two coats, using good lime and plaster of Paris.

Metal corner beads (of approved make) to be furnished and set by plasterer throughout first floor, main house.

Cornices. Cornices are to be run in accordance with detail drawings:

Schedule—To be used in living room, parlor, dining room, hall.

METAL WORK

Flashings. Wherever roofs come in contact with vertical surfaces 5-pound lead flashings, 9 by 9 inches, are to be built into each shingle joint and turned up onto the vertical surface at least 5 inches. Over these flashings, counter-flashings are to be placed, built into the brickwork as above specified; or, where the vertical surfaces are of shingle or siding, they are to extend under such surfaces at least 6 inches.

Valleys. All valleys are to be lined with 5-pound lead extending 6 inches under shingles at each side.

Eaves-Trough and Conductors. The eaves-troughs and conductors are to be of No. 26 galvanized iron, the conductors to be crimped 3 by 4 inches and connected 6 feet above ground with the 4-inch soil pipe to drain.

All work in connection with the eaves-troughs and conductors is to be riveted when possible, and all joints soldered; and the expansion and contraction from changes in temperature is to be guarded against by expansion joints or loose ends.

CARPENTER WORK

Framing

The building is to be full frame, and framed, braced, spiked, and pinned in the best and strongest manner, perfectly true and plumb. Filling-in studs shall be nailed, and door and window caps cut into studs. No woodwork shall come within one inch of a chimney; and framing must be arranged to avoid cutting for pipes, chimney, etc. Truss all openings over 3 feet wide.

Timbers. *Quality.* The timber, except where otherwise specified, is to be of spruce. All timber throughout the building to be full and square to the dimensions indicated, well seasoned, and free from large or loose knots, sap, shakes, or other imperfections impairing durability or strength.

Dimensions. Dimensions are to be as follows:

Sills, 6 by 8 inches
Girders, 8 by 10 inches
Posts, 4 by 8 inches
Girts, 4 by 8 inches
Ledger boards (used only in subordinate framing), 1 by 6-inch hard pine
Braces, 3 by 4 inches long
Studding, 2 by 4 inches, 16 inches on centers
Door and window studs, double, 2 by 4 inches
Door and window heads, 3 by 4 inches
Partition caps, 2 by 4 inches, hard pine
Partition soles, 2 by 4 inches
Joists, first and second floors, 2 by 10 inches; attic, 2 by 8 inches, 16 inches on centers
Plate, 2 by 4 inches, double, breaking joints
Rafters, 2 by 8 inches, 20 inches on centers
Valley rafters, 3 by 10 inches
Ridges, 2 by 8 inches
Piazza and porch girders, 4 by 8 inches
Piazza and porch sills, 4 by 8 inches
Piazza and porch floor beams, 2 by 8 inches, 20 inches on centers

Sills. Halve (or frame and pin) sills at angles. Frame corner posts and door and window studs to sill and girt. Floor beams are to be notched down on sill, and gained in.

Joists. Double the joists under all partitions not over partitions below running parallel with the joists, where supports to span are 10 feet or less; under all others, triple the joists.

Headers and Trimmers. Double all headers and trimmers 8 feet long or less; triple all longer ones.

Bridging. Bridge all floors every eight feet with 1- by 3-inch pieces, cut diagonally and double-nailed at each end.

Studs. All studs are to be 2 by 4 inches, 16 inches on centers, straight and plumb. Partitions directly over walls and girders in cellar, or with partition caps below, are to run down to rest on them. Strongly truss all partitions not supported from below. Spike studs at corners. Set studs of sliding door pockets on heavy paper and line pockets with ½-inch matched sheathing with tight joints.

Piazza Joists. Piazza joists are to pitch 1 inch in 5 feet away from the houses.

Main Roof. The main roof is to be framed in the strongest manner, with valley rafters carried to the ridge or hips. All hips and ridges are to be maintained perfectly straight. Rafters are to be notched over the plate and spiked. Double the rafters at

each side of dormer openings; 4- by 8-inch header, 8 feet above top floor. Partitions are to be carried up to support the roof wherever practicable. All are to be thoroughly tied, and made perfectly secure and strong. Collar beams are to be 2 by 6 inches, 8 feet 2 inches above attic floor.

Dormers. Dormers are to be framed with 4- by 4-inch corner posts, 2- by 4-inch studding and plate, and 2- by 6-inch rafters. The studding is to be notched 1 inch on rafters and to extend to the floor.

Boarding. Cover all roofs and frame walls with good, sound spruce boards not over 10 inches wide; roof is to be square-edged, the walls to be matched and laid diagonally. Cover walls with "Neponset" black sheathing paper, or its equal.

Shingles. *Roof.* Cover all roofs with "extra" sawed cedar shingles, laid 5 inches to the weather, with two nails to each shingle. Double-shingle all hips. The ridge is to be finished with 6- by ⅞-inch saddle boards.

Walls. Cover all walls with "clear" sawed cedar shingles, 5½ inches to the weather.

Exterior Finish

All exterior finish not otherwise specified is to be worked from good cypress, clear of sap, shakes, and large or black knots, following elevation and detail drawings; and to be put up in a skilful manner, with close joints and with nails sunk for puttying. Joints exposed to the weather are to be matched and painted with thick white lead before putting the pieces together. The painter is to prime finish before or immediately after putting up.

Main Cornices. Main cornices are to be according to detail drawings, with 5- by 7-inch cypress gutter, fascia, plancier, rebated 1¼-inch belt above clapboards, moldings, dentil course, and brackets.

Cellar Hatchway. Cellar hatchway is to have 2-inch plank treads on 2-inch carriages, 16 inches on centers; 2-inch plank sills, and trapdoor frame, bolted to masonry. Case with ⅞-inch cypress, and make doors of narrow cypress, the doors to be well cleated. Make water-tight. Put on heavy strap hinges and proper fastenings. Build single door at foot of stairs.

Porch and Piazza. *Floors.* The floors of porch and piazza are to be laid with ⅞-inch by 3-inch Georgia pine, dressed on one side, the upper edge eased off; laid ⅛ inch apart, and nailed with 8-penny nails. Finish with rounded nosing and ⅞-inch by 1-inch moldings. Floors are to pitch to throw off water.

Outside Steps. Steps are to be constructed with 2- by 10-inch plank carriages, 16 inches on centers.

Treads of outside steps are to be of 7/8-inch by 4-inch hard pine strips, with rounded nosings and coving under, returned at the ends. Risers are to be 7/8-inch thick.

Ceiling. Ceiling of covered porch and piazza to be of 5/8-inch by 2½-inch tongued, grooved, and beaded North Carolina pine.

Columns. Columns are to be built up of white pine, with turned shafts of diameter as shown for lower third, diminishing slightly above, with molded caps and molded bases.

Balustrade. At floor and at roof of porch and side piazza, and over dining-room bay, there is to be a balustrade, the balusters to be of 2¼-inch stock, 2 inches apart, turned.

Posts. Posts on porch and piazza roofs are to be built up with turned finials, and supported by pieces running up from the plate or sill inside of posts.

The top rail is to be built up and molded; the lower rail, 2 by 3 inches, is to be solid and beveled.

Window Frames. Plank frames in stonework in basement, except where shown double-hung, are to be of 1¾- by 6-inch pine, with 7/8- by 1¾-inch molded staff bead, and 2¾-inch sill. Frames are to be rebated on the outer edge for screens. Sash is to be hung at the top, to swing in.

All windows shown with meeting rail, unless otherwise specified, are to have pine frames made for double-hung sashes, with 7/8-inch hard pine pulley stiles, tongued into outside casings, beads, ¾-inch ground casings, 1⅜-inch yokes, 2¾-inch sills to pitch 1½ inches, 7/8-inch by 5-inch outside casing over boarding, with 1¾- by 2¼-inch back window caps, as shown. Windows are to have 2-inch bronze-faced axle pulleys.

Scuttle. The scuttle is to be 2 by 2 feet, with plank frame 6 inches high. Heavy strap hinges and fixtures are to be applied that will hold the cover at any angle. Frame and cover are to be tinned.

Door Frames and Doors. *Frames.* The frames are to be made from clear pine stock, 1⅞ inches thick, rebated and beaded on inner edge, and with 1¾-inch hard pine thresholds. The casing of outside door frames is to correspond with windows.

Sash. Sash is to be of white pine, unless otherwise specified. In the first story, it is to be 1¾ inches thick; in the second and third stories, and all of the ell, 1½ inches thick; in cellar 1¼ inches thick. Large one-light sash are to have 1½-inch meeting rails. Sash is not to be stained.

Doors. Doors, except stock doors, are to be paneled and molded according to scale and detail drawings. All panels are to be loose, and not glued or nailed. Tenons are to have ¾-inch haunches.

Outside veneered doors shall be 2¼ inches; doors 3 feet wide and over, shall be 2 inches thick; all others, 1¾ inches thick.

Front and Rear Hall Doors. These are to be 2¼ inches thick, of white pine, veneered inside to match vestibule; lower panels are to be raised, and upper panels glazed with double-thick glass.

Other Outside Doors. All other outside doors except cellar door shall be of 1¾-inch pine stock sash doors, as shown, with wood muntins, glazed with double-thick glass. Build cellar door of ⅞-inch stock.

Blinds. Blinds are to be hung for all windows. They are to be of cypress or of white pine, 1⅛ inches thick. Mark each blind to correspond with the mark on the window opening.

Screens. The Contractor shall furnish and set screens for all outside doors and windows that open; they shall be made from the best clear, thoroughly seasoned white pine, ⅞-inch thick, and shall be stained and varnished with three coats. Screens are to be fitted with lifts, springs, and runs, so that they can be used for either upper or lower half of sash, with adjustable run.

Wooden frames are to be covered with 14-mesh best approved galvanized wire, and door frames and cellar windows with 13-mesh wire.

Grounds and Furring. Fur ceilings and rafter in the finished portion of the attic with 1- by 2-inch spruce furring strips, 12 inches on centers, nailed to every beam; and fur out in finished attic rooms for 3-foot 6-inch walls; also for plastering next to basement walls, with 2- by 4-inch studding, set flat.

Put grounds for ¾-inch plastering around all door and window openings where there is no ground casing, and for base, wainscot, wood cornice, etc., as directed. Put two grounds behind base.

Interior Finish

Materials and Their Treatment. *Stock.* All stock is to be of the best quality, unless otherwise specified, free from knots or sap, thoroughly seasoned or kiln-dried. All must be smoothed, scraped, and sandpapered by hand before putting up, and at completion; such work as is to have a natural finish must be properly cleaned. No interior finish is to be taken into building until the plastering is dry.

Priming Back of Finish. Back of standing finish is to be given a priming coat by the Contractor who furnishes the interior finish, before it leaves his shop.

Curved Finish. All curved finish is to be spring on or worked from large stock, so that no kerf marks can be seen.

Finish for Main Part of House. All finish on main part of house, except inside of closets, is to be molded.

Finish for Service Parts of House. All parts of the building devoted to service, and the inside of closets, are to have flat finish.

Wainscot Sheathing. North Carolina pine, 4 feet high, is to be set in the back entry, the kitchen, and the bathroom; it is to be matched and beaded like approved sample, 7/8 inch by 2½ inches, with 1½-inch rebated cap and no base.

Paneled Wainscot. This wainscot is to be paneled, as shown, with raised panels; to be 3 feet high, have a 6-inch base, and a molded cap, 7/8-inch rails and stiles, and loose panels.

Schedule—To be used in dining-room.

Birch. Unless otherwise specified, all birch is to be the best selected, first-quality red birch, of even color.

Schedule—To be used in dining-room.

Oak. Unless otherwise specified, all oak is to be the best selected, thoroughly seasoned American quartered white oak; it shall show good grain, and be free from shakes, knots, stains, or any other imperfections.

North Carolina Hard Pine. Unless otherwise specified, the North Carolina hard pine used is to be of selected first quality.

Schedule—To be used in back entry; kitchen; pantry; china closet; bathroom.

Picture Moldings. Picture moldings, 1⅛ by 2½ inches, and of the same wood as the finish, are to be run around principal rooms of first story; around all chambers of second story, main house, moldings, 7/8- by ¾-inch and matching finish, are to be run. Unless otherwise directed, the molding is to be 1 foot 6 inches below ceiling, and where there is a cornice, ½ inch below cornice. The picture molding is to be finished by painter before putting up, except for the last coat.

Door Frames and Doors. *Frames.* All inside swinging doors are to have 1¾-inch double-rebated and beaded frames of pine or whitewood to match adjacent finish. Veneer for other woods with ¼-inch veneer on 1¼-inch pine.

Doors. Doors, except stock doors, are to be paneled and molded according to scale and detail drawings. All panels are to be loose and not glued or nailed. Tenons are to have ¾-inch haunches.

Doors not veneered are to be of solid pine, whitewood, cypress, or birch, to match room.

Doors in rooms having hardwood finish are to have thoroughly kiln-dried, white pine core, with solid moldings and ¼-inch veneering of kiln-dried wood ¾ inch on edges, well glued on both sides to match hardwood finish of rooms. If one of two adjacent rooms is to be painted, veneer door with hardwood of other room, on both sides. All panels over 15 inches wide to be glued up.

Stock Doors. Stock doors are to be 1¾ inches thick, stock sizes, with plain panels and flush moldings on both sides, and to have 4 panels. Architect must approve sample showing quality and arrangement of panels.

Sliding Doors. Sliding doors are to have astragal joints at center, and ⅝- by 1¼-inch friction mold all around; to slide on "Richards" or other approved patent hangers, on birch track.

Dwarf Doors. Dwarf doors for wardrobes, cupboards, pantry, etc., are to be solid paneled, 1¼ inches thick.

Closets. *Clothes Closets.* Each closet is to have a high shelf, and strips all around for clothes hooks. Unless otherwise directed, shelf is to be ⅞ inch by 14 inches, and 5 feet 10 inches above floor, with hook rows at 4 feet 6 inches and 5 feet 6 inches above floor.

Linen Closet. The linen closet is to have a counter shelf with four drawers below; shelves above, 16 inches apart, extending to ceiling, to be fitted with doors hinged at the bottom to drop down.

China Closet. The china closet is to have a counter shelf 2 feet 8 inches above floor; underneath, paneled, hinged doors and eight drawers, one drawer subdivided; above, hinged, glazed doors and five shelves. There is to be a frame for the sink, and a high closet over the sink with glazed doors and three shelves. There must be 8 inches clear space over counter shelf.

Pantry. The pantry is to have a counter shelf, as shown, 2 feet 8 inches high, with 4⅞- by 14-inch shelves above and four drawers below, one drawer being divided for knives, etc.; space for two flour bins with doors; remainder of space to have shelving enclosed by sheathed doors. All this is to be of clear white pine or whitewood, for natural finish.

Broom Rack. A broom rack is to be put up in broom closet or in cellar stairway; it is to have cast-iron holders for sweeping and whisk broom, dustpan, fire bucket, etc., which holders or fixtures are to be included in the hardware.

Tank in Attic. In the attic a tank, 4 by 4 by 2 feet, is to be built of 2-inch plank, tongued and grooved, fastened together with iron rods and nuts, and well cleated.

Plumbing Strips. Plumbing strips are to be put up to support pipe where required by plumbers. Water closet seats and tanks, except in attic, are to be furnished by plumber.

Mantels. Allow a total sum of one hundred twenty-five dol-

lars ($125.00) for wood mantels delivered at house, to be selected by Owner, set by carpenter, and finished by painter.

Floors. *Under Floors.* Lay under floors, except in basement, of good square-edged spruce boards, surfaced on one side to even thickness, and nailed to every bearing with two 8-penny nails. End joints are to be cut over beam in every case.

Sheathing Paper. Lay two thicknesses of approved sheathing paper between the under and finish floors.

Finish Floors. The upper floor is not to be laid, where there are double floors, until standing finish is all in place. All lining floors are to be thoroughly repaired and cleaned before finish floor is laid.

Oak Floors. For first floor of main house, except in kitchen, the floors are to be of matched quartered-oak flooring, 7/8 inch by 2½ inches, clear, thoroughly seasoned, and kiln-dried; to be blind-nailed to every bearing with 8-penny nails, laid over rough floor, planed off, scraped, and sandpapered, ready for finishing. Protect properly.

Hard Pine Floors. Hard pine floors are to be laid in kitchen, pantries, and bathroom, to be of 7/8-inch by 2½-inch matched rift Georgia pine.

Hardware. The sum of one hundred fifty dollars ($150.00) is allowed for all trimmings of doqrs and windows, and fittings in china closet, pantry, closets, drawers, etc., allowance to cover *net* cost to Contractor; Architect or Owner is to select hardware where he chooses; and Owner is to have benefit of any deduction from allowance. Carpenter is to furnish correct list of hardware, and to put it on carefully and in workmanlike manner.

PAINTING

Miscellaneous Requirements. *Samples.* Samples of all colors shall be submitted for Architect's approval.

Knots and Defects. Sap, pitch, knots, and similar defects shall be covered with good-quality shellac.

Number of Coats. Unless expressly so indicated, priming and shellacking are not to count as coats in this specification.

Exterior Finish. All dressed exterior finish, blinds, and sash, are to be painted two coats, after priming, of white lead and linseed oil.

Hard Pine. Pulley stiles and floors, and steps of porches, are to receive two coats oil, well rubbed in.

Schedule. Following is a general memorandum of exterior painting. This is to be compared with plans, and all work is to be left with painter's finish complete.

Finish, 2 coats paint after priming
Porch floors, 2 coats oil
Blinds, 3 coats
Metal, 3 coats
Shingles, natural

Inside Finish. Except where otherwise specified, all inside finish is to be well filled, and is to have one coat of stain and shellac and two coats of dead hard oil finish. All work about kitchen and bathrooms is to have two coats of hard oil with high gloss.

Ivory White. Where indicated, give 1 coat shellac, then 3 coats lead and oil paint, sandpapering each coat; then 2 coats white lead, zinc, and white varnish, rubbing down with pumice stone and oil. Sample and tint shall be approved.

Whitewood. Whitewood and other finish, unless otherwise specified, are to have 3 good coats lead and oil, color as approved; last coat is to have suitable proportion of zinc, and to be left with flat or oil finish.

Hardwood. Treat hardwood finish according to best methods with potash; give 1 coat of oil or paste filler; clean off; give 4 coats of white shellac, sandpapering after each coat except last, which is to be rubbed to dull finish with pumice stone and oil.

Enamel White. Give 1 coat shellac; then 4 coats lead and oil paint, sandpapering each coat; then 2 coats white varnish, rubbed each with pumice stone and oil, sample to be approved.

Standing Hard Pine Finish. Standing hard pine finish is to be given 1 coat approved primer and filler, sandpapered; 1 coat approved inside spar varnish, rubbed down; and 1 coat approved inside spar varnish, flowed on.

Schedule—To be used in kitchen; pantry; serving-room; bathroom.

Bathtub. Bathtub is to be painted outside, 4 coats; the last coat to be an enamel gloss coat.

Exposed Piping. All piping that shows is to be given 1 coat of white shellac.

Plastered Walls and Ceilings. Plaster walls, except in bathroom, and ceilings, except in kitchen, pantry, china closet, and bathroom, are to be painted 1 coat sizing and 3 coats paint, last coat to contain varnish to leave gloss. All ceilings are to be sized and tinted.

GLAZING

Plate Glass. Furnish and set ¼-inch American polished plate glass for large lights in main house.

Double-Thick Glass. All glass not otherwise specified is to be first-quality double-thick German or American glass.

At completion, all glass is to be thoroughly cleaned of oil, putty, paint, mortar, and plaster, and to be left whole.

HEATING

Furnace. Provide and set up complete, where shown on plans, a hot-air furnace of *approved* make, to be of *cast iron,* with stated and sufficient area of grate and heating capacity to keep building at 70 degrees Fahrenheit, when thermometer is at zero outside.

Piping System. *Smoke Pipe.* The smoke pipe is to be 9-inch black iron pipe, fitted with close-fitting damper, also a check damper, and proper cleanouts.

Tinwork. Furnish and set warm-air pipes and register boxes, of bright I X tinplate. Mark each pipe with the name of room it supplies. Cover risers with metal lath in partitions before plastering.

Dampers, Collars, etc. The dampers for warm-air pipes, netting for register boxes, tin collars, casings, lining tin for protection from fire are all to be supplied and set by Contractor.

Cold-Air Box. The cold-air box is to be of No. 24 galvanized iron, with all joints riveted tight, and with such bracing as will effectually prevent the sagging of the top. It is to be fitted to the cold-air inlet and at delivery inlet, and is to have a balanced, close-fitting damper which, when open, will give full passageway for air.

Registers. Furnish registers and connect to pipes, with valves in each. Registers are to be of black Japanned cast iron, with tin boxes and borders. In the library, register is to be bronze; in the reception room, of white enamel, of approved quality and design.

> Schedule—Registers are to be laid out according to an approved schedule submitted by each bidder, showing size, finish, etc., for each room, with size of supply pipe. Locations are to be as shown on plans or as approved in building, before proceeding with work.

PLUMBING

Piping and Connections. *Materials.* All drain, soil, waste, and vent pipes, and all fittings, are to be extra heavy plain cast iron, painted outside two coats red lead.

Joints. All joints in cast iron pipe are to be made tight with oakum and lead, well calked.

Lead Pipes. All lead, waste, and vent pipe branches are to be of best quality drawn lead, of the following weights per foot:

1½-inch	3 lb.
2 -inch	4 lb.
3 -inch	6 lb.
4 -inch	8 lb.

Connections. All connections of lead and iron pipes are to be made by heavy brass ferrules, same size as lead, calked with lead.

Joints between ferrules and lead pipes are to be wiped; all lead pipe joints are to be wiped.

Pipe Supports. All vertical lines of soil and waste pipes, if not carried to drain below cellar floor, are to rest on brick piers at their base.

Iron Pipes. All vertical lines of iron pipe are to be held in place by pipe hangers or wrought-iron clamps, placed 5 feet apart. In horizontal lines, they must be not more than 10 feet apart.

Lead Pipes. All lead pipes are to be secured in place with metal tacks or brass clamps, placed 3 feet apart; and horizontal pipes are to be supported their entire length by carrying strips.

Brass Pipes. All brass pipes are to be secured by brass pipe holders, approved by the Architect.

Miscellaneous Piping Requirements. *Pitch of Pipe.* All horizontal drain and waste pipes are to have a fall of not less than ¼ inch to the foot.

Angle of Connections. All changes in direction must be made with Y (45 degrees), ⅛ (22½ degrees), or $\frac{1}{16}$ (11¼ degrees), branches.

All connections with horizontal pipes must be made by Y branches. TY's (sometimes called "Sanitary T's") may be used on vertical pipes.

Brasswork. All exposed brasswork is to be nickel-plated, except in basement and kitchen, where it is to be polished.

Cleanouts. Set Y's with extra heavy brass screw caps at each bend in horizontal lines, and 15 feet apart in straight lines; also set cleanouts at ends of all horizontal lines.

All cleanouts are to be the same diameter as the pipes with which they are connected.

Traps and Vents. Every fixture must be separately trapped. No traps are to be less than 1½ inches in diameter. Each set of trays must have one trap.

All traps must be vented—4-inch traps by 2-inch branches, 2-inch and 1½-inch traps by 1½-inch branches.

Roof Flashings. All joints between the roof and iron pipes must be made tight with 6-pound lead or 16-ounce copper flashings.

Drains, Soil and Waste Pipes. The plumber shall make proper connections from a point 10 feet outside of building, with a drain, by 5-inch iron pipe.

Just inside the house wall, place a 5-inch running trap with two cleanouts; and run a 5-inch fresh-air pipe from house side of trap to a point not less than 15 feet from building, opening one foot above ground, with return bend.

Continue drain 5 inches in diameter under cellar wall, and connect the various soil and waste pipes with same.

The trap on the main drain must be placed in an accessible brick manhole, with 8-inch walls, and be covered with stone or iron cover; and the drain pipes must be laid in a brick trench with stone or iron cover.

Set, where shown on plans, lines of 4-inch soil pipe, or 2-inch waste pipe, as necessary, with proper connections to receive the various fixtures. Carry the pipe through roof, and one foot above same, increased one inch in diameter from a point below roof; ends above roof are to be left free and unobstructed.

For each line of fixtures, set a 2-inch pipe, with fittings for the various vents. Connect with soil pipe below lowest fixture, and at top well above highest fixture.

All waterclosets are to have 2-inch local vents of nickel-plated copper connected to 3-inch spiral galvanized pipe, carried to chimney, as directed by Architect. All joints in pipes are to be soldered tight.

Under the refrigerator, place a copper-lined box, 12 by 8 by 6 inches. Carry 1½-inch lead waste pipe from box to basement, with end turned up so as to form a water-sealed trap, and capped with light flap valve, to waste into sink or other receptacle provided for the purpose.

Tests. The water test must be applied to the entire system of piping, in the Architect's presence and to his satisfaction. All pipes and connections must remain uncovered until they have passed the test.

On completion of the work, after all fixtures are set, the smoke test will be applied, and must prove satisfactory to the Architect.

Fixtures. *Watercloset.* Waterclosets are to be installed as follows:

In basement—one washdown closet, with metal outlet of approved pattern, and with oak seat (no cover) attached to bowl with heavy hinges. The tank is to be a plain 12-ounce copper-lined siphon tank with cast-brass gooseneck, valve, high-pressure ballcock, iron brackets, chain and pull, and 1½-inch brass flush pipe. Brass work is to be polished.

In bathroom—one siphon-jet closet, with water-covered outlet connection between earthenware and waste pipe; 1¼-inch cherry seat and cover, with heavy hinges, attached to bowl. The tank is to be a cherry service tank, 8 gallons' capacity, with brass brackets,

high-pressure ball cock, and 1½-inch flush pipe. Brasswork is to be nickel-plated.

Lavatory. In the bathroom there is to be installed one 22-by 27-inch enameled-iron lavatory, with back and apron in one piece, supported on concealed wall hangers; it is to have heavy, low-down pattern compression cocks, disc handles, ½-inch iron-size brass supply pipes, and 1½-inch deep-seal S-pattern trap. Brasswork is to be nickel-plated.

Bath. In the bathroom there is to be installed one 5-foot guaranteed quality, 3-inch roll-rim, enameled-iron bath, flat bottom, approved pattern; it is to have ¾-inch heavy combination compression cock, disc handles, ¾-inch supply pipes, 1½-inch connected waste and overflow pipes, and plug and chain. Outside of bath is to be finished by painter. Bath is to waste through 1½-inch bath trap set in floor.

Sinks. Sinks are to be installed as follows:

In kitchen—one 36- by 24- by 8-inch soapstone sink, with 12-inch back, and soap dish, set on galvanized-iron standards. Sink is to waste through 6-inch lead trap, and to be supplied through ¾-inch compression bibs; hose end on cold cock; brasswork to be polished.

In china closet—one 24 by 14-inch recessed, 18-ounce, tinned-copper sink, with 1½-inch standing waste and overflow. Waste is to be the same as in case of kitchen sink, and supply through tall gooseneck with heavy pattern compression cocks; hose end on cold cock; brasswork to be nickel-plated.

Wash Trays. In the laundry there are to be two 24-inch soapstone trays, with 12-inch back, and soap dish, plugs and chains. Trays are to be set on galvanized-iron standards.

Range Boiler. Range boiler is to be of copper, 40 gallons' capacity, on galvanized-iron stand, and connected with range by ¾-inch brass pipe.

All fixtures except water closets are to be supplied with hot and cold water.

Water Supply. *Materials, etc.* All cold-water pipes and fittings are to be of galvanized iron; and all hot-water and circulating pipes are to be iron-size brass, semi-annealed, with all fittings of brass.

Where exposed, brass or nickel-plated pipes are to be supported by brass or nickel-plated hangers.

All exposed supply pipes in bathroom and toilet rooms are to be nickel-plated brass, semi-annealed; in kitchen, polished brass.

Stops and Wastes. All risers are to have stop and waste, roundway same size as pipe, in accessible position in cellar, and properly tagged.

All supply pipes and branches shall have proper pitch so that they may be readily emptied at their lowest point; and each branch supply of fixtures shall have compression stops, with stuffing box close to cocks.

Size of Pipes. Make connection with water main in street by ¾-inch, 4-pound lead pipe; and carry same into building. Just inside wall, place a ¾-inch "Simplex" stop, with ¾-inch stuffing box hose bib on house side. From stopcock, carry galvanized pipe along on basement ceiling, and take branches to supply various fixtures, as may be necessary.

From ¾-inch main, take branches as follows:

For risers	¾ inch
For sill cocks	¾ inch
For tank in attic	¾ inch

Supplies to fixtures shall be as follows:

To lavatory and watercloset tanks	½ inch
To baths, sinks, and wash trays	¾ inch
From tank in attic to hot-water boiler	¾ inch

Attic Tank. In attic, where directed by Architect, line a 4- by 4- by 2-inch tank with 14-ounce tinned copper, fitted with ¾-inch high-pressure ball cock and proper valves. Overflow is to run to roof or to laundry traps in basement, as may be directed by the Architect.

Set, where directed by Architect, two ¾-inch nickel-plated wheel-handle sill cocks, with stuffing box. Inside of wall, place a ¾-inch "Simplex" stop and waste.

Hot Water System. Connect hot-water boiler with tank by ¾-inch pipe. Carry ¾-inch brass pipe from boiler, with branches as specified to supply the various fixtures, and ½-inch brass return to boiler. The entire system must circulate freely and thoroughly.

From highest point of system, carry ½-inch expansion pipe to tank, discharging over top of same. Place stop cocks on supply to boiler and from same.

GASFITTING

Provide and put in gas piping according to this specification, and as shown on plan, according to the rules of the local gaslight company.

The cutting is to be done by the carpenter, not by the gasfitter. No floor beams are to be cut farther than 2 feet from bearings.

Piping. Piping is to be of wrought iron; fittings are to be of galvanized malleable iron, set with red lead, firmly fastened.

Make sure that pipe is free from obstructions, before placing in position. Gasfitters' cement must not be used.

Following is the scale of sizes of pipes and number of burners (not outlets) to be supplied therefrom:

Longest run (ft.)	20	30	50	70	100	150
Size of pipe (in.)	⅜	½	¾	1	1½	2
Number of burners	2	4	15	25	40	70

Testing. Piping is to be tight under a pressure of air equal to a column of mercury 6 inches high, mercury to stand without failing for half an hour. Outlet caps are to be loosened to show that they affect testing apparatus, and that there is no obstruction in pipes.

VACUUM CLEANER

Provide, install, and connect up complete in first-class operative condition, to the approval of the Architect, a vacuum cleaning machine of one sweeper capacity, for the purpose of removing dust and other foreign matter from carpets, rugs, cushions, upholstery, floors, walls, and other interior surfaces. The vacuum cleaning machine shall include all mechanisms incidental to the complete and perfect operation of the system, and all equipment shall be of the most recent and perfected design.

The contractor shall install the machine, as herein specified, and all piping required to make the system complete, including cleaner mains, risers, and exhaust pipe. All electrical connections are to be made by owner.

Permits. The Contractor shall obtain permits, arrange for inspection, and furnish without cost to owner all certificates of inspection required by the city or local authorities on the entire equipment.

Foundation. A substantial floor shall be provided by Owner in the room in which the vacuum cleaner machine will be located.

Equipment. *Vacuum Cleaning Machine.* The Cortractor shall furnish and install, where shown on plans, one No. —— Vacuum Cleaner.

Tools. The Contractor shall furnish one set of tools as follows:

1 Carpet or rug renovator
1 Felt bare-floor sweeper
1 Renovator for upholstery, portieres, clothing, etc.
1 Renovator for tuft cleaning
1 Duster

Extension handles sufficient for use with above tools, and such that walls, ceilings, or hangings can be easily reached from the floor

All tools must be well made, durable, and of polished aluminum or nickel-plated finish.

Furnish two 25-foot lengths non-collapsible vacuum hose, of not less than 1 inch inside diameter, and having smooth inside surface. The hose is to be the best quality, reinforced in a manner to prevent collapse at highest vacuum obtainable with the pump furnished.

Each length of hose and each extension handle must be equipped with a quick-acting coupling. Simple slip joints will not be acceptable.

Piping. Provide and install piping for vacuum cleaning system, located as indicated by the Architect, and consisting of two vertical risers of 1½-inch pipe, and necessary horizontal mains, connecting the risers with the vacuum cleaner. The exhaust pipe from the vacuum cleaner is to be carried into a vent flue or to an unobjectionable point outside the building, as indicated by the Architect, and to be of the same size as connection provided for it on vacuum cleaner. The pipe used must be of standard weight, with smooth inside surface, free from dents, kinks, fins or burrs. The ends of all pipe are to be squared and reamed smooth to the full inside diameter. All piping and joints must be thoroughly tested and guaranteed free from leaks.

Fittings. All fittings must be those known as "drainage fittings," made of gray cast iron, free from defects, having inside diameter through body of same size as pipe bore; long-turn tees and elbows to be used. All openings in fittings receiving inlet couplings are to be 1½ inches, pipe size.

Pipe-Joint Paste. In the installation of the piping, under this specification, pipe-joint paste, red or white lead, must be applied only to male threads of pipe and fittings.

Hangers. Horizontal overhead pipes are to be supported by suitable pipe hangers, spaced not more than 12 feet apart.

Cleanout Plugs. Brass cleanout plugs, of same size as pipe, are to be provided in horizontal mains at turns and at base of risers.

Inlet Couplings. The following openings are to be equipped with inlet couplings:

Basement, 1	First story, 2
Second story, 2	Third story, 1

Decorating. All exposed piping in finished rooms is to be decorated with paint or bronze, two coats, as directed by the Architect.

SPECIFICATIONS FOR CITY WORK

While many of the preceding requirements relate to both country and city construction, there are certain details that are peculiar to each, so that a specification adapted to city work will next be considered.

PRELIMINARY STUDIES

For illustrations in connection with the following pages, the construction of a city house is selected, on a corner lot fronting 100 feet on the avenue, and 150 feet deep on the side street, a party wall on the inside line. The house is to come out to the avenue sidewalk line, with coal vaults under sidewalk. The avenue in front is paved, with curb and sidewalk in place. There are no improvements of this character on the side street.

Study of Drawings. A careful outline of what the specification is to treat should be made before any of the actual writing is begun; and inasmuch as the scheme has been developed on the drawings, and the only object of the specification is to supplement these, a most careful study of the drawings should be made, keeping in mind the question of conditions and materials. Notes should be taken of the different classes of subjects which will supply the headings for the specification; and very largely on the arrangement and completeness of these notes will depend the success of the specification, which should never be begun until the last note is taken and the whole arranged in proper sequence.

Study of Site. With the completed scheme in mind, the site is visited and studied as carefully as were the drawings. It is found that a fence is necessary to prevent careless teamsters from driving over the adjoining property. The curb and sidewalk have been placed under the direction of the city authorities, and they must be carefully protected. There is a large tree on the lot, which, with two in the street, must be saved. In matters of this kind it is useless to stipulate that the contractor is to be responsible for any damage to the tree, and then leave it unprotected. After some teamster has damaged it, there is nothing the contractor

can do to put it back or to pay for the damage. Definite means of protection should be included in the contract work. There will be little use to try to preserve sod or shrubs. When the work is completed, it will usually be found that the grades are changed just enough to destroy the sod, and that the shrubs had better be located elsewhere. All the room on the lot will be valuable to the contractor for working space and piling material, and this point he will not fail to take into account in making his bid; or—to put it otherwise—if he is confined to narrow quarters and required to protect the grass and shrubs, he will add a round figure for the additional work and inconvenience.

Study of City Regulations. The city authorities must be consulted relative to the amount of roadway which may be used, the guards required in the way of barricades, temporary sidewalks, and red lights at night.

The questions of where the sewer and the water main are to be tapped must be settled; and it is usually better to have both connections made under a special contract before any work is done under the general contract, as the sewer will possibly be needed to keep storm water from the excavated space, and water will be needed at once for masonry work. If the street has been paved, it is probable that both sewer and water main have been brought to the curb.

Study of Soil. It will be of advantage, if, at this point, the owner will have three or four small test holes dug. Borings are of doubtful value; and often, in uncertain soil, a great additional expense is entailed after the award of the contract on account of necessary substructure work. Not infrequently clauses are inserted in the specifications, requiring the contractor to be responsible for any bad spots found, and to do all necessary work to make them good, so that test pits are considered unnecessary. Since, however, under such conditions, the contractor will always figure for the worst conditions, and the owner pays for it, it is better to know definitely the kind of bottom that will underlie the building. In digging these pits, the knowledge of the various kinds of soils to be encountered will be of value. The specification writer can estimate with certainty then how much material can be used for filling and grading of the lot, and how much worthless mate-

rial must be hauled away. If any sand is encountered, tests should be made to determine its value for mortar.* This knowledge will have its influence on the bidders in making up their proposals.

It is not here presumed that the case under consideration involves extensive protection of adjoining walls, or that excavation is to be carried below, or that shoring must be done. Such cases are comparatively rare; and, as each instance involves questions not of a general nature, it is outside the scope of a paper of this character to discuss this phase.

STUDIES IN MATERIALS

Since the primary object of this paper is instruction, there are introduced here certain problems relative to the particular qualities of the material under consideration. Special attention is called to the fact that these problems are not intended merely to illustrate the qualities of the particular material, but to indicate lines of *thought* to be followed in considering *every* material.

There are a great many things taken for granted in connection with building material—many old beaten paths which lead one from tradition to nowhere. The sooner the specification writer accustoms himself to testing everything he handles, the sooner he will be master of the situation. If this work is ignored, and he follows only well-worn tracks, and the information of "material men," he will be in "hot water" most of the time.

In specifying materials, one maxim should always govern: *Never specify a quality which you cannot demonstrate exists; or forbid a quality or ingredient you cannot detect.* For instance, if you are not prepared to have a chemical analysis made of the Portland cement, do not say anything about sulphur or magnesia; clauses of this kind may sound well, but they may also cause you trouble, if later you cannot tell anything about the composition of the material. If you rely on the analyses as made by the manufacturers, you can depend on it that you will never find a cement with a harmful percentage of either.

* See later discussion of "Studies in Materials."

The problems relative to materials will be discussed under the following headings—*sand, cement, lumber, and roof materials.* In addition to the work along the lines laid out, the powers of observation should be so cultivated that, in the daily routine, wherever work is encountered, the eye will be ever ready to detect any phase of development in material.

SAND

Essential Qualities. Sand will be considered only in connection with cement (Portland cement).* The province of sand with cement is, on a small scale, similar to that of brick in masonry. The cement acts in the same capacity as the mortar surrounding the brick. If a brick could be made the size of the complete wall there would be no need for mortar, but as it cannot, mortar is required to fill thoroughly all spaces between the bricks and to adhere to each tenaciously so as to form one solid mass. If on the sides of the brick should be placed thin layers of soft clay, the bond would be broken, inasmuch as the clay would not cling tenaciously to the brick and would prevent contact between the brick and the mortar; therefore, to obtain a good brick wall, each brick must be clean and free from a coating of foreign material, so that contact with the mortar will be complete.

To return to sand—in the same way each particle must be entirely separate from any other, and must be free from foreign

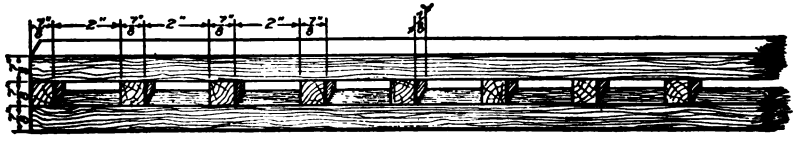

Fig. 1. Molds for Making Sand-Testing Bricks.

coatings which would prevent its contact with the cement or would cause the particles to cling together so that a thorough coating of each particle with cement would be impossible. The usual requirements for sand in cement work is that it shall be "clean, coarse, and sharp." Rarely should more than three volumes of sand be

* See discussion of "Cement."

used to one volume of cement, but for our building we must be more economical. We find in the pits on the site a soft, fine sand, which, while it separates well, resembles ground clay when rubbed between the fingers. Before throwing it out as useless and paying a round price for sand hauled in, let us see what can be done with it.

Tests. The sand may be tested by using the material to make sample cement bricks.

Make frames of wood screwed together which will provide 32 molds for bricks 2 inches long, with 7/8-inch section, Fig. 1, using two long strips 7/8-inch square divided by 7/8-inch strips so as to leave 2 inches clear between each, all to be oiled. Obtain some clean, coarse, sharp sand for comparison, and also some of the fine soft sand from the site; carefully mix (dry) sand of both kinds with cement in four different proportions—first in the proportion of 3 parts sand to 1 cement, then of 4 parts sand to 1 cement, then of 5 parts sand to 1 cement, and lastly of 6 parts sand to 1 cement—eight batches in all. Make enough of each batch to mold four bricks. Mix each batch with the greatest thoroughness, in order that every side of every particle of sand shall become coated; then add just enough water to dampen thoroughly, and crowd the mixtures into the molds (which should be laid on a smooth plank, for bottom), compressing each as much as possible. If water appears on top, it will indicate that too much has been used in mixing. Place on each brick an identifying mark, such as

No. 1	3-1, standard sand	No. 5	3-1, common sand
No. 2	4-1, standard sand	No. 6	4-1, common sand
No. 3	5-1, standard sand	No. 7	5-1, common sand
No. 4	6-1, standard sand	No. 8	6-1, common sand

Cover with a damp cloth to prevent evaporation; and after one day draw out the screws holding the forms, and keep the bricks moist for two weeks—either covered with a wet cloth or immersed in water.

At the end of that time the test of the bricks for crushing strength should be made. Obtain first two good, smooth planks about 3 feet long by 1 foot wide, then go to a neighboring foundry, and get permission to use their scales and a few hundred pounds of pig iron; lay down one plank on a perfectly level bed, and on

it place the No. 8 bricks on their sides, Fig. 2. In order to get an even bearing it is well to put below and above the cement bricks one layer of soft building paper; on top place the second plank with great care, seeing that it has a firm, even bearing at each of the four bricks. Now carefully lay pig iron on the upper plank, beginning at the middle, and loading toward each end, never filling one side before the other or with a much heavier load. Carefully watch the bricks; note when they crack, and when they crumble; weigh the pig iron, and note the results.

Test each of the remaining seven sets of bricks in the same way.

It is safe for ordinary dwellings to select the cheapest materials and mixture which will carry under such conditions 500 pounds

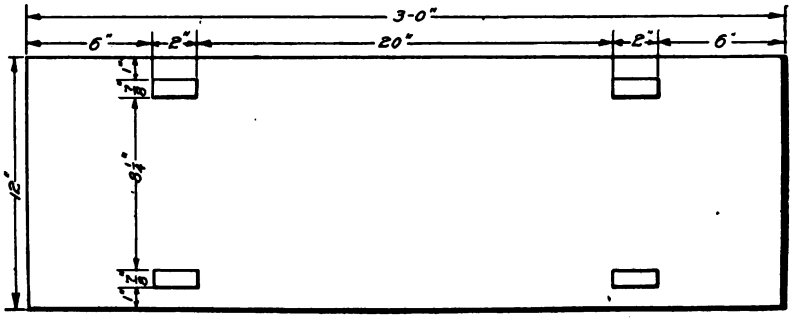

Fig. 2. Planks with Bricks Located for Crushing Test.

of iron. For example, it is supposed that No. 3 sample, made up of 5 parts standard coarse sand to 1 part cement, carries the same load as No. 6, made of 4 parts sand from the site to 1 part cement. If it costs $1.50 for one cubic yard of coarse sand, and $0.50 a yard to haul the sand away from the excavation, the coarse sand costs us for use $2.00 a cubic yard or $0.074 cents a cubic foot. With cement at $2.00 a barrel, the total cost would be as follows:

Cost of 5 cu. ft. sand	$0.37
Cost of 1 cu. ft. cement	0.67
Cost of 5 cu. ft. mortar*	$1.04
∴Cost of 1 cu. ft. mortar	$0.20⅘

* When sand and cement are mixed in proper proportions, the bulk of the mixture is not (theoretically) greater than the bulk of the sand, as the cement only fills the voids or spaces between the particles of sand, just as there can be poured into a full measure of shot 20 per cent of water without overflowing the measure.

Using sand from the site in mixture No. 6 (4 parts sand to 1 cement), we have the cost per cubic foot as follows:

Cost of 4 cu. ft. sand	$0.00
Cost of 1 cu. ft. cement	$0.67
Cost of 4 cu. ft. mortar	$0.67
∴ Cost of 1 cu. ft. mortar	$0.16¾

It will thus be seen that it is cheaper to use the 4 to 1 mixture and the poorer sand from the site, than to haul the sand away, bring in other sand, and use less cement. If, on the other hand, it is found that it will require No. 5 to equal No. 3, it will be cheaper to haul away the excavated sand and haul in good sand.

Before breaking the bricks, they should be very carefully examined as to texture and firmness. Scratching with the finger nail will show the general quality to the student after a short experience; experiment with weights is therefore unnecessary after the student has become familiar with the appearance of good mortar.

After the bricks are broken, examine the fractures, and observe with a glass how well the spaces between the particles of sand are filled. Generally the results will be about as follows:

No. 1 will show much greater strength than No. 5
No. 2 will not be of much greater strength than No. 6
No. 3 will perhaps break under less weight than No. 7
No. 4 will break and crumble long before No. 8

The reasons for these differences are readily detected under a glass. The imported coarse sand requires much more cement to fill the spaces. In No. 1 they are all filled; while in No. 4 there are large voids, which do not occur to such an extent in Nos. 7 and 8; the sand being finer allows smaller voids. *Observe* that the increase in the number of voids or small holes in the mass weakens the mixture.

Now try one other experiment. Get two forms from which 4-inch cubes can be made. Make a mixture of, say, 4 parts fine sand to 1 part cement; mix half of it with a large amount of water, as is usually done in ordinary work, and from this form a 4-inch cube. Mix the other half with just enough water to change throughout the color of the mass, and from this make another 4-inch cube. Crowd the mixtures into the form, both cubes to be compressed as

much as possible; set the cubes aside, covered with a wet cloth for a week; then split with a cold chisel, and observe. The interior make-up of that mixed with a larger amount of water is full of voids; that mixed with little water is compact.

The question of sand is treated, as later the question of roofs will be, with a great deal of "home-made" detail, not only to get at the question of sand and roofs, but to illustrate how, with materials that are always at hand, results of great practical value may be obtained.

CEMENT

There is probably no other building material of which so much has been written as cement within the last ten years; and there will be no attempt here to discuss the question except from an extremely practical standpoint. All things considered, Portland cement at $2.00 a barrel net is the most economical material for general masonry. Lime is much cheaper, but of very doubtful value as generally made. The English, Scotch, and French use lime with great success; but it is always slaked in pits for at least three months prior to use, and is treated and worked so as to make it valuable for mortar, while in this country the lime undergoes such crude treatment that it cannot be considered a material suitable for good work. Therefore lime in any form will not be further considered for masonry work.

Classes of Product. There are now three classes of Portland cement on sale in this country. By far the largest class is that ground from an artificial clinker. Second are those known as slag cements, ground largely from furnace slag. While in much of the product of the second class the sulphur has been so far extracted as to make it identical in chemical analysis with the cement of the first class, and of great value in general masonry, it is wiser to avoid the use of slag cement where surfaces are exposed to wear, as in sidewalks, steps, etc. Unless the work is of minor importance slag cement should not be used unless such chemical tests (independent of tests made by the manufacturers) can be obtained as will show that the sulphur therein is below 2 per cent.

The third class is one imported from Belgium under various brands carrying English names, such as "Eagle", "Star", etc., the

packages showing, however, the place of manufacture. These cements are generally coarse and of low grade—possibly the factory's second grade, on which the manufacturer does not care to put his regular brand.

English cement is practically out of the market.

A few brands of German remain, like the "Dykerhoff", which commands a high price and for which there is a limited demand from users who believe there is no other from which equally good results can be obtained. For our purposes, however, the second and third classes need not be considered; the range in the first is wide, and little if anything is gained in price in using either of the others.

Tests. On important work, tests should be made to determine the fineness of grinding, specific gravity, time of initial and final set, soundness, the proportion of silica to lime, and the amount of sulphur and magnesia. Tests are also made of tensile strength; but since this is a quality never required of cement, and this test only indirectly bears on other necessary qualities, and since the presence of matter which is likely to cause final disintegration, tends often—in the early stages of use—to increase the tensile strength, such tests should be in no way relied on.

In this paper, only three tests which it is possible for the student to make with appliances easily obtained, will be considered.

Fineness. To test for fineness, what is known as a 100-mesh sieve—that is, a sieve with 100 spaces to an inch—should be obtained. Any first-class hardware store can furnish the wire either from stock or on order, and a home-made sieve can be constructed. A small quantity of cement should be weighed and most carefully sifted; 90 per cent of the material should pass through the sieve. By referring to statements relative to cement, made under "Sand", the student will understand that extreme fineness is required in order that the cement may fit in and completely fill any voids which may exist between the particles of sand.

Initial Set. The time for the initial set is determined approximately as follows:

Mix a small amount of neat cement (clear cement without sand) with water, to the consistency of stiff mortar; observe the time it takes to set hard enough to prevent an indentation when on it is

placed a wire about 6 inches long and of $\frac{1}{12}$-inch diameter loaded with a ¼-pound ball on top. The time should not be less than 30 minutes.

It is unwise to use cement which sets at once or in so short a time that it can hardly be placed before the set occurs. Cement fresh from the works often takes its first set quickly; but after it has attained an age of two or three months it improves in this respect. Therefore, never specify "fresh cement," as cement should not be used within three months from the date of its manufacture.

It should be noted that the setting quality of cement consists in the *permanent* union of water with the cement. The setting of cement mortar is often referred to as the "drying out"; as a matter of fact, the water necessary for mixing the mortar never leaves it unless driven off by extreme heat. This may be proved by a simple experiment. Take a tin can with tight cover; weigh out five pounds of dry cement; mix with it enough water to wet it; pack it in the can and thoroughly compress it. If water rises to the top—indicating that too much has been added—pour it off; put on the cover tight, and weigh the whole, to determine the amount of water added; then set it away for two weeks. At the end of the time, open the can and put it in a warm, dry place for a few days so that the cement may be thoroughly dry, then weigh. It will be found that the weight is that of the original cement plus the water added, which still remains in the mass. Subject the cement to extreme heat, and it will be found that the water is thrown off, the cement becomes fine again, and its weight corresponds with that originally used.

Soundness. This is one of the most important physical tests, for it indicates whether there probably exist elements which will eventually disintegrate the mass. Test pats must be made and their action carefully observed; if warping, cracking, or blotches appear, the material should not be used. Form on small pieces of clean glass four pats of cement mixed with only so much water as will turn the color of the cement. The pats should be about 3 inches in diameter and ½ inch thick in the center, tapering to the edge, which should be as thin as possible. After the pats have been for a day under a damp cloth, put two of them in water for a week,

and leave two in air, then examine for the symptoms referred to above.

Should it be possible to test the material chemically, the following points should be observed:

The amount of lime should be slightly over three times that of the silica. Thus, if there is 20 per cent silica, the lime should run from 60 to 62 per cent. The silica should not fall below 19 per cent, or rise above 22 per cent, and this is about the range of good cements on the market.

More than 2 per cent of sulphur should never be allowed. The reason for this is that the setting of cement is a process in which the various materials combined unite chemically to form one solid mass. Sulphur in its various forms is an ingredient which does not work in harmony with the other materials; while it does not at once prevent the satisfactory combination and setting of the other materials, yet under conditions that are very likely to prevail it sets up a chemical action tending to disintegrate the mass in time.

Magnesia can generally be considered an ingredient which has no value either as sand or cement, being what is known as "inert" material. While 4 per cent may not injure masonry, wearing surfaces should not have over 3 per cent.

The manufacturers of Portland cement have tried to eliminate both of these ingredients—but so far without success at a cost which would make it possible to sell the cement at a profit.

The specific gravity should not fall below 3.10, as a low specific gravity indicates poor burning of the clinker.

These later tests, however, are delicate laboratory operations, and only experienced chemists are capable of getting satisfactory results.

Non-staining Cements. There is a very general prejudice against the use of the ordinary Portland cement for setting limestone, sandstone, and marble, the theory being that the moisture from the mixture, in getting away, travels through the stone, carrying with it certain staining matter, which is either deposited on the surface or unites chemically with ingredients in the air to stain the face. For this reason there have come to be used certain mate-

rials of much less structural value than the Portland cement. These are called *non-staining* cements, and are sold at a high price.

There are also on the market many materials intended to be put on the back of stone, which, the manufacturers assert, will prevent the passage of moisture and staining matter. While it can easily be demonstrated that water containing cement running over the face of soft stones does leave distinct traces, it is a different thing to show that such stone or marble can be stained by materials in the joints or on the back. It is well, before any amount of money is spent, to experiment in producing the stain on the stone used with the ordinary cement.

This may be done by filling a small box with soft mortar, and placing therein a piece of stone or marble, so laid that the top surface is ⅛ inch above the mortar. Then tack a piece of waterproof paper to the box sides, and cut a hole somewhat smaller than the upper face of the stone or marble sample used, using weights to bring the inner edge of the paper to the stone so that practically no moisture can pass except through the sample and off from the exposed surface. The results of the so-called staining qualities of ordinary cement can in this way be determined.

LUMBER FOR CONSTRUCTION AND FINISH

Local conditions affect very much the grading of lumber. While the great lumber interests formulate and publish schedules of grades, the user cannot, from their designations and descriptions of grades alone, make an economical selection. The designations "first" or "best quality," "without imperfections," etc., inserted in specifications to describe the quality desired, tend to make trouble for everyone concerned on account of the various meanings put on these terms.

Some markets are well supplied with good spruce framing lumber, while an adjoining section will have no spruce but will have good rough pine or hemlock. The same differences will be found relative to finishing lumber. The student should visit each lumber yard, look over the stocks, find materials in that market and how they are graded; he is then prepared to state in the specifications just what imperfections can be allowed in framing timber, boards, or finishing lumber, but he must always bear in

mind that there is no material in existence which is free from imperfections. By observing the defects and stating clearly what will be allowed and what will not, he can avoid very many unpleasant misunderstandings, with the owner especially, and also with the builder.

Lumber which has the largest number of good qualities is the most expensive; therefore, for each portion of the work, only that material should be required which has the particular qualities required for that particular place.

Since in the case of lumber the questions of grade, quality, etc., can be determined by observation rather than by such experiments as are indicated for cement or sand, these matters will not be further treated here; but in the following specifications, there will be illustrated what consideration should be given generally to lumber grades, quality, and finishes.

ROOFING MATERIAL

Value of "Thinking in Construction." In the previous examples or problems attention has been given to putting the student in line of *thinking in materials.* In this section consideration will be given to the combination of materials in a roof covering, partly because a good roof is one of the prime necessities of a successful structure, and also because, in a brief study of one type of roof of which a model can easily be constructed, the elements of how *to think in construction* within the province of the specification can be clearly illustrated.

The particular covering here considered is canvas. Undoubtedly each student is familiar with the use of canvas for boats—from steamships, sailing vessels, etc., the decks of which are covered with canvas—down to the small duck boat completely constructed of this material; but it is possible that few have ever considered the various steps necessary to make it available for water and wear-resisting uses.

Study of Canvas as Roof Covering. Canvas, in its natural condition, is far from waterproof, and is one of the materials most easily and quickly destroyed by mildew. Its one original desirable quality is its extreme strength and toughness. Therefore there must be incorporated with this toughness the properties of resisting

the passage of water and the ravages of decay. To prove to yourself how tough a material canvas is, take a good sample of 10-ounce duck; put it on a board, and strike a dozen times in one place; take it up, rub it in the hands, and observe how little damage has been done to the texture. The following experiment will show how the other essential qualities are added:

Build up of 7/8-inch matched flooring, dressed on the upper side, a board about 3 feet square, putting 2- by 4-inch cleats on the underside. These cleats represent the rafters, the 7/8-inch stuff, the roof boards. Obtain from different stores samples of 10-ounce duck, and mark each for identification, making a schedule in which the price of each is noted. Cut all samples to exactly the same size; and, after drying thoroughly to drive off all moisture, have them weighed by a druggist on very accurate scales, noting on the schedule the weight of each piece. Soak and wash each thoroughly, rubbing so as to remove all size or filling *soluble in water*. After the samples are thoroughly dry, have each carefully weighed again, and note the weights on the schedule. From this schedule can easily be determined which is the best material for the money. It may be found, for example, after soaking out all soluble matter, that the canvas which costs 18 cents a yard is considerably cheaper than that costing 17 cents.

A choice having been made, buy a yard; and, when thoroughly dry, secure it to the boards prepared, using ordinary tacks, about 5/8-inch long, spaced one inch apart; stretch the cloth as much as possible so that it will be tight and flat. Wet it thoroughly and *observe* that wetting has a *tendency* to shrink it; but, as it cannot shrink because it is securely nailed to the board, each thread is drawn very tight and made smaller. A close examination will show that the spaces between the threads are increased and that water runs through as through a sieve. While the canvas is in this condition, put on a good coat of white lead and oil paint (this is about the only material which should be painted wet), and *observe* that a large amount of paint is taken up; in fact, the paint goes through the openings between the threads, reaching and covering the underside of the cotton. The water does not unite with the paint, and passes off before the paint dries, allowing the threads to swell into the soft paint, so that when the paint is dry the fabric

is practically imbedded in it, with less on the upper surface than anywhere else. Two more coats on top are necessary. This treatment protects the canvas from mildew and makes it waterproof; the original fabric furnishes the strength.

After the paint is dry, subject the sample to the harshest of treatment. Grind with the heel, drop bricks, etc., to see just how much it will resist; if not successful in making a hole, use a hatchet, patching the hole so made by tacking over it a piece of duck of sufficient size to cover it; wetting it, and painting it, etc., as before. When dry, place the boards level, nail down 1-inch strips around the edge, laid in white lead, and cover with one inch of water. Let this stand for forty-eight hours. Now cut up the duck, and see if any leaks exist; if so, carefully examine the covering to determine exactly the cause. Next, roll the duck loosely, and put away for two weeks in a dark, damp place, and then examine for mildew.

It is not the intention in using this illustration merely to explain how a canvas roof is made, but to set the student to thinking about roofs. A shingle roof, or a tar-and-gravel roof, or a slate roof, differs only in the manner in which it accomplishes the same ends. All other types of roofing should be observed and studied along similar lines, so that the proper material will be used in each of the different varieties of buildings.

ELECTRIC WIRING

Special Nature of Wiring Specifications. The item of electric wiring, while entirely within the province of the architect to lay out, is of such a mechanical nature that it is rarely advisable to include it in the general specification. Few general rules outside of a set adopted by the National Board of Fire Underwriters—called the "National Electric Code"—can be formulated.

The arrangement, location, and sizes of wires are problems involving delicate adjustment in order to obviate danger from fire, to prevent loss of power, and to obtain a perfectly satisfactory service at all points under the maximum load, and yet keep the amount of material down so as to avoid unnecessary expense.

Expensive instruments are necessary for the testing of the system when complete, and a considerable experience is needed

even for stating in a specification what tests are to be applied in each specific case. Therefore it is not deemed best to discuss the matter further here, except to state that for work such as that under consideration, the services of an engineer in the employ of the electric light company which is to furnish the energy can generally be obtained to lay out the system and to test the completed work.

OUTLINE SPECIFICATIONS

In studying the following outline specification, it is suggested that many trade papers and the general magazines advertise appliances used in building, and that a postal card request to the advertisers will bring very useful information about the product advertised. Especially is this true as regards cement, concrete, stone, brick, paints, varnishes, plastering material, plumbing goods, and heating goods.

Catalogues of the last two are particularly easy to obtain and are well worth studying. If the student finds himself especially impressed with any one system or brand of goods, he should make it a point to learn about other materials or systems which are used for the same purpose, until he finds some which, he is satisfied, are equally good. The man who has only one material he can use, or one way of accomplishing a certain object, is sure to be either deficient in information or unduly influenced; there is no one material, or one way of doing anything that is best in all respects.

The student should also have a copy of some of the many handbooks of general information relative to materials. Of these, probably Trautwine will be found the most useful; for, while it is not so popular as some, it is a high authority, and in it will be found notes on every variety of material and construction.

SPECIFICATIONS

FOR A RESIDENCE BUILDING TO BE ERECTED FOR

JOHN DOE

THE CORNER OF A AVENUE AND B STREET, CHICAGO, ILLINOIS

Richard Roe, Architect

GENERAL CONDITIONS

Contract Drawings. The drawings which will with this specification form the basis of an agreement for the erection and completion of a residence for John Doe, to be erected at the corner of A Avenue and B Street, are numbered 1, 2, 3, 4, 5, 6, 7, to a scale of ¼ inch to the foot; and details, 20, 21, 22, 23, to a scale of 1½ inches. All materials and work necessary to complete the structure indicated, are to be furnished and done by the Contractor.

It is the intention that the general scheme for the work shall be illustrated by the drawings, on which all dimensions and sizes are given. When features or details are evidently of a similar nature to those already shown, they will not be carried out in detail; but in all such cases the Contractor will complete the work in accordance with the evident intent of the drawings.

The materials are in general designated; and when the drawings are competent to show fully what is required, it will not be within the province of the specification, or details to be prepared later, to make further reference thereto.

Detail Drawings. Full-sized details and models will be furnished as the work progresses, and no work requiring them is to be done before their delivery. In their preparation, minor modifications may be made which do not materially affect the cost of execution. The drawings will be delivered to the Contractor within the following periods after the award of the contract:

For construction of exterior walls, cornice, roof, or material framing ..... 6 weeks
For interior finish ..... 4 months
For carving on material in place ..... 6 months

Specifications. It is the intention that this specification shall cover those points with regard to materials which the drawings are not competent to cover; and the fact that certain items are indicated on the drawings, and not mentioned herein, shall not relieve the Contractor from furnishing them. It is the intention that the drawings and this specification shall so co-operate that all matters in connection with the proposed structure necessary for making accurate estimates for the completion of the building, shall be fully set forth. There are, however, certain operations and materials obviously necessary for the construction; and unless these are of unusual nature, no mention thereof will be made, but such fact shall not relieve the Contractor from his obligation to provide for all such items.

Changes in Plans. No alterations shall be made involving change in cost, unless ordered by the Architect in writing. The

written order must set forth fully the nature and extent of the change, and the terms and conditions under which it is to be made, and to it the assent of both Owner and Contractor is to be attached.

The Architect shall, during the progress of the work, give oral directions relative thereto; but such directions shall not be considered as authorizing changes.

Acceptance and Rejection of Materials. The decision of the Architect shall be final relative to the work and materials furnished, and the materials rejected are to be removed promptly from the site. It shall be understood, however, that every item furnished in place in the building which is covered by a payment, is considered as accepted, and shall not be later rejected unless defects develop which were not visible prior to the payment; and when, for such cause, material is rejected, the entire expense incident to replacing the material is to be borne by the Contractor.

Responsibility of Contractor. The Contractor is to be entirely responsible for producing the finished work in place; and in carrying it out, he is to furnish all tools and temporary appliances to accomplish the contract requirements; he must also supply heat, so that after the first plaster coat is begun no part of the building shall be allowed to have a temperature lower than 40 degrees Fahrenheit. If plastering is done in hot, dry weather, Contractor is to protect the building with such temporary closures as will prevent injury from too rapid evaporation. He is to be responsible for the protection, not only of all material delivered on the site, but also of all materials in place, until the acceptance of the building as evidenced by the final payment on the contract and the delivery of the structure to the Owner. As this responsibility extends to loss by fire, he is to keep the building fully insured in stock insurance companies, the loss, if any, payable to the Owner as his interest may appear. The total amount of such insurance shall never be less than a sum 20 per cent higher than the total amount of the payments made; and prior to each payment, the Contractor shall deliver to the Owner such policies.

The Contractor shall, if required by the Owner four days prior to the time any payment is due, produce evidence satisfactory to the Owner that such settlements have been made as will clear the premises from the liability of liens on account of either labor or materials furnished; and in case the Contractor fails to produce such evidence, the Owner is not under any obligations to make the payment until his demand is complied with. If the demand is not made by the Owner four days prior to the day any payment is due, the Contractor shall not be obliged to furnish evidence for the payment then coming due; but the right to demand the evidence before any subsequent payment is made, will continue to exist, so

that the Owner may demand such evidence prior to any future payment.

Compliance with City Laws. The Contractor, without the intervention of either Owner or Architect, is to comply with all city ordinances for the regulation of building on private property and the temporary use of highways beyond the building lines.

Employer's Liability Insurance. Should any person, whether employed by the Contractor or not, or any property, be injured in any of the operations in connection with the building or through the carelessness of the Contractor or any of his employes, the Contractor is to be responsible therefor; and he must, consequently, carry at all times employer's liability insurance which will cover up to $5,000 the damage to any one person, either of the public or of those in his employ.

Ladders and Scaffolds. The Contractor is to maintain at all times such ladders and scaffolding as will afford the Owner or Architect access to all portions of the work.

Samples of Materials. As soon as possible after the award of the contract, the Contractor is to deliver on the site samples of all materials required in connection therewith. Since the samples are to indicate the range in the materials he proposes to use, they should represent both the poorest quality and the best in each class, the understanding being that the material furnished is to run between the two, so that the average of the material will be practically the average between the two samples.

The Architect shall pass on these samples; and after acceptance by him, they are to be kept for guidance in passing on the material when delivered. If any of the samples, in the opinion of the Architect, are not in accord with the contract requirements, he shall reject such in writing, setting forth fully his reasons, and the Contractor is to furnish additional samples in lieu of those rejected, until materials suitable, in the judgment of the Architect, are submitted. In executing the work, the poorer materials are to be placed in the minor portions of the work, as selected by the Architect.

Contractor's Foreman. The Contractor is to have a representative, fully empowered to act in all cases for him, on the site whenever any work is in progress or any material is being delivered; and neither the Owner nor the Architect shall give to anyone, except such representative, any directions or instructions. Should such representative not give proper attention to such directions or instructions, such neglect will be sufficient cause for refusal on the part of the Owner to make further payments until the settlement of the questions involved.

Architect. The Architect is the technical adviser for the Owner, and shall have the general direction and oversight of the building operations, with the right, conceded by both Owner and Contractor, to accept or reject finally materials or workmanship, to decide the amount due at each payment period, and to determine when the Contractor has complied with the conditions of his agreement.

He is not to be responsible for such questions as those relating to liability for liens, or for such other matters of business detail as do not require the technical training for architectural practice.

As the Architect must depend on the clear requirements of the drawings and specifications for his authority in exercising his duties, it is desirable that all questions which may arise be fully settled therein, so far as practicable, before the submission of bids. Therefore all parties who propose to submit bids should, in writing, call attention to any points which in their judgment are not fully explained by the drawings and specifications, at least six days before the time set for receipt of proposals; and such questions, with the replies thereto, will be forwarded to each prospective bidder. The failure of any bidder to ask for such supplementary information will be construed, after the award of the contract, as barring him from demurring from any ruling which in the opinion of the Architect is justified by the contract requirements. In any questions of a technical character which may arise between the Owner and Contractor, the Owner shall be governed by the decision of the Architect.

Payments. Before beginning the work, the Contractor, if he so desires, can prepare for the Architect a statement showing the order in which he will proceed with the construction of the building; and a schedule of the quantities of all items entering into the work, with the value of each in place—the total of such values to be the contract price. If, in the judgment of the Architect, this schedule is perfectly fair, it shall be adopted as a basis of the monthly estimate of the value of the work satisfactorily in place; and on the third day of each month, the Owner shall pay on the contract price 90 per cent of the value of the materials satisfactorily in place on the first, as determined by the schedule; but in these estimates, no account shall, under any circumstances, be taken of the value of materials not finally incorporated in the building.

If, however, the Contractor does not elect to prepare such a schedule, or prepares a schedule evidently not fair to the Owner, then the Owner shall pay to the Contractor on the third of each month 90 per cent of the value of the materials satisfactorily in place, as determined by the Architect's estimate; and in determining the value, the Architect is to be governed by the total contract

price, so that at all times there will be reserved by the Owner sufficient funds to complete the building, in case of default on the part of the Contractor, at usual market rates, and, in addition, 10 per cent.

Time of Completion. The time limit for the completion of the work shall be nine months from the date of award of contract; and it shall be a condition of the contract, that there will be deducted from the final payment the sum of fifteen dollars ($15.00) as liquidated damages for each day's delay after the expiration of such period, until the final acceptance of the work by the Architect and its delivery to the Owner.

Protection of Lot. Put a tight board fence 5 feet high, with three 2- by 4-inch rails, and with 4- by 4-inch posts set 6 feet on centers, which will protect adjoining property from encroachment during building operations.

On the street side, and in front of the spot to be occupied by the building on the avenue, enclose such portion of the roadway as is permitted by the city building ordinance to be used in building operations; build also such fence, and place such walks as are required by such ordinance.

On the site is one oak tree, and in the street two elm trees. These are to be protected by tree boxes of 2-inch plank and 2- by 4-inch cleats, with such holes cut on sides as will permit a full circulation of air about the trunk; under no circumstances are any guy ropes to be secured to, or allowed to interfere with, any portion of the trees.

There will be no attempt to save any of the sod or shrubs now on the site, and the Contractor will be allowed all the space for piling material, etc.

The protection by the Contractor, of trees, sidewalk, curb, adjoining property, etc., as required hereinafter, shall not relieve the Contractor from responsibility for any injury which may occur to such protected items on account of the building operations.

EXCAVATION

Disposition of Excavated Materials. Four test pits have been dug to a point one foot below the bottom of all footings; and bidders should visit the site and examine the conditions. The black soil which constitutes the top stratum is all to be piled on the lot, wherever the Contractor desires, so long as it is not against the oak tree. Below the black soil is a stratum of sand which is satisfactory for concrete and cement mortar; below this is coarse gravel which may be used for concrete, provided all stones which will not pass through a 2-inch ring are cracked to such size. Any other

material to be taken from the excavation is worthless, and must be hauled away.

The excavation is to be carried on so that different strata will be kept in separate piles. Any materials mixed so as to make it undesirable in the opinion of the Architect to use them for the purposes above designated, are to be hauled away.

Shoring. The curbstone in place is to be protected by sheet piling driven down just back of the inside of curb line so that there will be no settlement or shifting before the supporting wall is completed.

The other sides of the excavations are to be sloped enough to prevent caving.

The excavation is not to go below the party wall of the adjoining building.

All excavations for footings must be complete before any footings are placed.

Backfilling. After all foundation walls are completed and thoroughly set, backfilling is to be done with sand or gravel.

Sewer and Water Connections. The sewer and water have already been brought to the site. The sewer terminates at a brick manhole, 3 feet 6 inches inside diameter, with iron cover, at grade about 5 feet from the side line of the building; and temporary connections with this manhole are to be made, so that there shall be at no time any standing water in the excavation, should it develop that the gravel is a water-bearing stratum.

The water connections will be encountered, in making the wall at the curb line, about 4 feet below grade.

MASONRY

Materials Required

Cement. All cement is to be Portland cement, of such fineness that 90 per cent will pass through a 100-mesh sieve. The initial set shall be in not less than 30 minutes; and pats of neat cement, about 3 inches in diameter and ½ inch thick in center, worked off to a thin edge, which has been exposed in air or immersed in water for seven days, after the cement has set sufficiently not to be disintegrated by water, shall show no discoloration, warping, checks, or signs of disintegration.

Sand. The sand shown to be on the site by the test pits is of sufficiently good quality for all masonry mortar except wearing surface of pavements, steps, etc. Should there not be enough thus obtained, that brought in must be as clean and sharp as that found in excavating.

The sand for all wearing surfaces, such as walks, steps, and

cellar and area floors, down for at least ½ inch, is to be crushed granite, ranging from the finest material to that which will pass a 30-mesh sieve.

Broken Stone. The gravel stratum may be used for concrete aggregate, provided the sand and all stone too large to pass a 2-inch ring are screened out. The sand may be used with other sand on the site, and the stone screened out be broken to size required; the other material needed shall be equal to that obtained on the site, and the Contractor shall not dig holes below the finished grade lines to obtain material.

Brick. *Common Brick.* All *common* brick are to be run of the kiln, excluding salmon brick, which will take up during one hour's immersion in water as much as 18 per cent of their weight in water. As delivered, the hardest are to be kept in piles for use in backing exterior walls and flues; the softer are to be put in interior walls.

Facing Brick. All *facing* brick are to be of light color and rough face texture; evenness of tone or burning will not be required; and the light and dark tones will be laid together, with no attempt to keep the same tones together; but no brick shall be allowed which is soft enough to absorb over 12 per cent of its weight in water. The facing brick are to have full square edges, free from chipped corners.

Granite. The exterior wall below water table, and the front steps and buttresses, are to be of granite. All granite is to be of light color, free from black knots, and is to be finished 4-cut work. The joints are to be ⅜ inch wide, and tooled back full for 1 inch from exterior surface. The stones may be as thin as economical dressing will permit.

Soft Stone. From water table up to the line of the second-story window sills, all stone required is to be a light limestone or sandstone with a 4-bat-to-the-inch finish (consisting of 4 concave grooves to each inch, made either by hand or by machine) for all vertical surfaces. All other surfaces shall be rubbed. The stone must be of an even texture, free from seams or streaks. Should any material used show in a rubbed block any grain from which the natural bed can be determined, it is to be set so that it will rest on its natural bed; but if the stone is of such character as to show no such indications, it will be immaterial whether or not it rests on its natural bed.

The ashlar may be as thin as 4 inches, except where reveals or corners occur. At reveals the heads are to be the full depth; and no vertical joint in the face of the wall is to be nearer the reveal than 1 foot, while all caps and sills are to be the full depth.

Terra Cotta. *Structural.* The interior faces of all exterior

brick walls are to be furred with 2-inch porous terra cotta of such quality that a nail can be driven therein without splitting, and firmly held.

All flues are to be lined with hard-burned non-porous flue linings, at least ¾ inch thick.

Ornamental. All ornamental terra cotta for cornice and balustrade is to have a color similar to the lighter tones of brick, with a combed surface forming about 6 ribs to one inch. The terra cotta is to be hard-burned, with capacity to absorb not over 4 per cent of its weight of water after immersion for one hour. All approximately horizontal surfaces are to be made rough, to key the cement coat which it is proposed to put above. The finished pieces are to be straight and unwarped, and in lengths never less than 2 feet 10 inches for continuous members; in projecting members, all vertical joints must occur over bearings. All members with less than 2-feet face must be in one piece. The Contractor must furnish shop drawings for approval of jointing only; no outlines are to be modified thereby, and such changes in the jointings may be made, within the lines previously laid down, as in the judgment of the Architect will better the construction or appearance of the work.

Masonry Construction

Concrete Work. The concrete work of all footings and exterior foundation walls below grade, shall be composed of 1 part Portland cement, 4 parts sand, and 7 parts screened gravel or broken stone. In order to make these proportions efficient, it will be necessary, in mixing and applying the materials, to use great care. The Contractor, under direction of the Architect, shall construct a cube of the mixture about 18 inches square, to show its possibilities when carefully manipulated; this standard shall be the one by which the work will be judged, and any portion of the concrete work which falls below this standard will be condemned. The sand and cement must first be thoroughly mixed dry, turning it over at least four times if no machine is employed, so that no uncolored particles of sand can be detected; after which, just enough water is to be added to dampen the mass thoroughly. The aggregate is then to be mixed in, wet.

Walls. It will be necessary to place plank forms for all footings and walls; the concrete is to be put in such forms, and thoroughly rammed. A smooth surface like a spade is to be forced down, just inside the planking, to force the aggregate back from both faces of the wall until clear motar only shows. The walls of each portion are to be carried up the full height rapidly, and the planking to be so arranged that it can be removed from any part within two days after the placing of the concrete. Both faces of

the wall are to be finished smooth with a trowel, the surface being so compressed as to make it proof against ground moisture.

Basement Floor. After the lining of the first floor has been laid, the basement floor is to be put in. On the base of concrete 3 inches thick, composed as for footings, put, before it has set, a wearing surface ½ inch thick, composed of 1 part cement to 3 parts crushed granite, troweled to a smooth, level surface.

Beams and Slabs over Sidewalk Cellar. Reinforced concrete beams and slabs over the sidewalk coal cellar, are to be composed of 1 part Portland cement, 3 parts sand, and 5 parts gravel or broken stone which will pass through a ¾-inch ring. This is to be tamped in the forms and around the reinforcing metal, to form a solid, compact mass. As the strength of this slab is dependent principally on the care in mixing the material and in placing it, it must be tested three weeks after it is set, by placing five layers of brick over the entire surface. If under this test it fails or cracks, it is to be removed and replaced at the Contractor's expense.

Sidewalk. After the completion of the building, a sidewalk, in all respects matching that now in place, is to be continued over the concrete slab, and the iron coalhole cover frame is to be built in so as to set flush with the surface.

Brickwork. *Rough Brick Walls and Chimneys.* The rough brick partition walls in basement, and all chimneys and the backing of all exterior walls, shall be laid and thoroughly imbedded in Portland cement mortar, 1 part cement to 4 parts sand; all brick are to be thoroughly drenched before being laid. In backing up stonework, the brick is to be so bonded that it can be brought up approximately level with the top of each stone course; there is to be placed in every horizontal stone joint a sheet of No. 24 expanded metal, extending to within 1 inch of the face of the stone and through the full thickness of the brick wall. This is to be free from rust, and at once imbedded in the mortar joints of stone and brick to form a reinforced concrete bond.

Every fifth course of rough brick is to be of headers.

Where rough brick walls will be exposed to view, the joints shall be trowel-pointed and all mortar kept off the face.

Chimney Openings in Wall and Fireplace. At the base of ash pits, set doors 8 inches by 12 inches.

At the base of chimney flues, set doors 6 inches by 8 inches.

In each fireplace hearth, there is to be a small cast-iron ash dump with cast-iron frames built in and anchored.

Terra cotta pipe thimbles are to be built in, 1 foot from the finished ceilings, as follows:

1—8-inch thimble in heater cellar
1—6-inch thimble in laundry
1—6-inch thimble in kitchen

Fireplaces. The fireplaces are to be built complete with firebrick backs and facings, all laid flat, as the chimney is constructed. Special-shaped firebrick, with ends molded so as to conform to the line of the facing and bevel of the jambs, are to be used at the angles between facing and jambs.

All brick below the flat arch are to be laid in fire clay with close joints; and in each joint a strip of No. 24 expanded metal is to be built, extending within ½ inch of the face of the brick and leaving at least 4 inches to build into the mortar joint of backing. In the throat, put cast-iron flue-stops, with dampers which can easily be closed from below.

The flat arches *above* are to be laid in Portland cement mortar, with No. 24 expanded metal extending through each joint to within ½ inch of exposed faces and sticking up 4 inches. When this is complete, a reinforced concrete beam is to be formed above, in which brick ties are to be imbedded, in addition to six strands of No. 8 twisted wire fencing.

The flue linings of hard terra cotta are to be set close; and any which are crooked or broken in handling shall be rejected.

Facing Brick. Facing brick shall be used for the visible surfaces of the exterior brick walls and chimneys. Each course will alternate headers and stretchers, and the facing and backing are to be carried up together and of such size brick that the headers of every fifth course will bond. The header of all other courses may be half-brick. The joints shall be approximately ½ inch thick, and trowel-pointed as the work is laid; all mortar must be kept off the face.

Over the windows, flat arches are to be formed, bonded, as required for the fireplaces, to the concrete beam formed back of the arch.

Setting of Granite and Soft Stone. The joints of all stonework are to be ⅜ inch thick, with expanded metal, as required above, the mortar to be of the same composition as for brick.

The Contractor will be responsible for any staining of the faces of the stone. He will be permitted to use such brand of cement as he may consider safe, provided in the tests it conforms to the requirements of Portland cement as stated under "Cement."

NOTE TO STUDENT. No. 1.—In order that the student may ascertain to what extent he is grasping the situation, he should, at this point, and before proceeding further with this specification, spend at least six hours on masonry work in progress in his vicinity, observing work which corresponds to that referred to in this outline specification. He should ask questions of such foremen or workmen as he is able to approach, regarding the details of construction and materials used. He should see the men who furnish the material, and obtain from them the prices, and also find out about different grades of the material.

Under no circumstances are notes to be taken. The student must absorb the information in such a way that he will *remember it.* After the conclusion of these investigations, he should take four days in which to think over the situation as observed. After the four days of *thinking,* he should write a specification, not exceeding 400 words in length, for some particular portion of the work or materials observed, giving special attention to covering the most ground possible with specified number of words.

Setting Terra Cotta. *Structural.* All furring terra cotta is to be set in Portland cement mortar. As a 1 to 4 mixture would be too short for the thin edges, the mortar must be a 1 to 2½ mix; one 30-d spike is to be driven into the brick mortar joints, with head projecting 1½ inches into furring joint for tie.

Ornamental. All joints are to be ½ inch thick, and special anchors, shown on the detail, are to be built in. Fill all hollow portions with concrete formed by running in cement mortar and then crowding in broken bricks until the mortar is forced into every corner.

Over all approximately horizontal surfaces, put a ½-inch coat of 1 to 1 Portland cement mortar, after covering the surface with a continuous sheet of No. 24 expanded metal. The terra cotta surface is to be thoroughly wet, the mortar coat pressed vigorously through the metal, and the surface finished smooth. This surface is to be protected from the sun for four days, and wet at such intervals as will keep it at all times moist.

CARPENTRY

Materials Required

Rough Lumber. All wood which is not exposed to view in rooms above basement, may be of pine, spruce, or hemlock, sized and seasoned.

Joists and Stringers. Joists and stair stringers must be sound, with no loose knots, or knots over 2½ inches, measured the longest way, within 3 inches of the lower or within 1 inch of the upper edge.

Studs. All miscellaneous studs must be sound, with no loose knots in either edge.

Rough Floors. There will be no wood floors in basement. Cover all joists and rafters with tongued and grooved pine or spruce boards, ⅞ inch thick and not over 5 inches wide, for lining. Shakes and other imperfections, which do not leave holes, will be accepted, provided the imperfection is of such a character that it will firmly hold a nail.

Miscellaneous. All miscellaneous framing lumber, bridging, etc., must be sound.

Finishing Lumber. *Floors.* All finished floors of the first and second story shall be of quartered white oak; and all floors above shall be of edge-grain pine, tongued and grooved, with not over 2½ inches face, thoroughly kiln-dried, and of a quality free from shakes. Sound knots will be allowed; also imperfections which do not extend to within ¼ inch of the wearing surface.

Basement. There will be no finish in basement, except door frames and doors, which will be stock pattern and paneled 1¾ inches thick.

First-Floor Rooms. The finishing lumber for all rooms on first floor except kitchen, pantries, and closets, shall be of quartered white oak, with bright surface, and with no imperfections which appear on the face or exposed edges; but sound knots of any size, which are finished smooth, will be allowed. All other finishing lumber of first and second floors is to be of oak, ash, or birch, of a quality specified above, but may be straight-sawed.

Second-Floor Rooms. All finishing lumber above second floor is to be of pine, of a quality containing no defects which one coat of shellac and three coats of paint will not cover.

Shelving. All shelving in closets and pantries throughout the building, may be of pine or poplar, full ⅞ inch thick.

Stairs. All stair treads, rails, balusters, and risers are to be of quartered white oak, the treads to be 1⅛ inches thick, all strings to be of the same wood as the finish of adjoining floors.

Miscellaneous. All lumber for grounds, window-frames, etc., may be of pine or spruce, with square edges and free from loose knots.

Carpentry Construction

Framing. *Joists.* All *joists* are to be set 1 foot 4 inches on centers, with a bearing on all supporting walls of 4 inches. In brick walls, the ends are to be beveled so that the upper edge is just on a line with the inside face of wall.

Every third joist in the brick wall is to be anchored thereto by a strap anchor containing ½ square inch of metal, extending 2 feet onto the lower edge of joist and within 4 inches of the outside face of wall, the end turned up 2 inches, to be spiked to the joist with five 30-d nails to each anchor. Where joists meet over partition heads, they are to be spiked thereto with four 20-d spikes at each bearing, and, when practicable, to the joist of the opposite side. All joists are to be cross-bridged every 8 feet of clear span, with 2- by 2-inch stuff, with two 12-d nails in each end.

Trimmers. All *trimmers* are to be doubled, and all *headers* over 10 feet long are to be tripled. Where joists are framed together, no cutting is to be done; but wrought-iron hangers or

stirrups with a cross-section of all vertical parts equal to 1 square inch of metal, are to be used.

Studs. All studs are to be 1 foot 4 inches on centers, both studs and heads doubled beside and over all openings; and all openings over 4 feet wide are to be trussed above. Each stud is to be secured with four 12-d nails at each end, and to have one line of 2- by 2-inch single bridging in the height of each story, this bridging to be so set in the center of the stud that it will be an inch back from both faces.

Rough Floors. The *lining floors* shall have two 8-d nails in each board over each bearing, one in the tongue and one about 1 inch from the groove edge. All lining shall be so laid as to be perfectly tight, and may be laid before plastering.

Sash. All *sash* shall be of pine, 1¾ inches thick. When only single sash are shown, they are to be hinged with three 3-inch wrought-iron butts at the top, and have two hooks to each sash to secure them when either closed or open. All other sash are to be double-hung with braided cotton cord and iron weights, the pockets of the window frames to be as long as practicable.

Finish. *Floors.* All *finished floors* shall have one 8-d nail over each joist; and, after being laid, they are to be scraped or planed to an even surface. These floors are to be laid after all other finish is in, and are to be cut with great care against the base.

Lumber. All *finish lumber* is to be put up in such a manner that the nails or screws securing it will be invisible. This is to be done by working through the back or in quirks or concealed places, but no splintering to hide the heads of nails shall be required.

Doors. The hardwood *doors* are to be veneered on soft white pine cores made of strips not over ⅞ inch thick. Before the veneering is put on, the Architect is to be advised where the cores may be inspected; and, if the gluing or seasoning is defective, or hard knots are discovered, the cores shall be rejected. The panels are to be left free to shrink. The doors below the third floor are to be 1¾ inches thick; those on third floor and above, 1⅜ inches thick.

Mantels. The *mantels* are to be built up complete, all parts glued together and nailed or screwed in concealed places, and brought to the building ready to set in place.

Hardware. The Owner shall furnish mortise locks complete, 3 butts for each door, 2 sash lifts, 1 sash lock, 1 socket, and 4 sash pulleys for each window.

The Contractor is to set these and to furnish and set any other hardware evidently necessary to complete the work—such as wrought-iron brackets for shelves, sliding-door hangers, etc.

Roof. The flat portions of the roof are to be covered with canvas. The steep portions shall be covered with tile.

Canvas. All canvas must weigh, when thoroughly dry, 10 ounces to the square yard, and must not lose over 5 per cent of its dry weight after being soaked in water 10 hours and so rubbed as to take out all matter soluble in water. It is to be laid dry, stretched tight, all edges to be lapped 1 inch and tacked with ¾-inch tacks set ¾ inch apart.

In all places where the roof meets a vertical surface, three-cornered strips, 1½ by 1½ inches are to be nailed, and the canvas is to be carried up over them and 8 inches on the vertical wall. If such wall is of masonry, there shall be a 1⅛-inch by 2½-inch dressed strip, fastened by expansion bolts set 3 feet apart under the projecting ledge of brick; the canvas is to be tacked to the underside of this strip, as at other places.

After the entire roof is covered and the canvas swept clean, it is to be soaked with water, and, when thoroughly wet is to be rubbed full of stiff paint composed of white lead and raw oil in proportions of 100 pounds of lead to 3½ gallons of oil. When this is dry and the surface hard—not less than five days after the first application—the roof and all exposed surfaces of wood strips in connection therewith are to have two coats of white lead and oil paint.

Tile. The steep portions of the roof are to be covered with red tile burned from a tough clay; and all nails or wire necessary to secure them permanently to the roof are to be of copper. If wire is used, the gage is to be not less than No. 12; if nails, the gage is to be not less than No. 8.

All joints are to be so close that there will be no necessity for waterproof paper below, or for cement, except at the hips.

All valleys are to be open, and flashed with 14-ounce copper, which *must* extend not less than 8 inches under the tile at each side.

NOTE TO STUDENT. No. 2.—See Note 1, on page 70, relative to examination of actual masonry work. At this point the student is to follow the directions in No. 1, only applying them to carpentry work and materials, and to write a specification (not exceeding 400 words) of some portion as directed in Note No. 1.

Gutters and Conductors. All gutters and exterior conductor pipes shall be of 16-ounce copper; where they join the soil pipe system, they are to be soldered to cast-brass thimbles, which are to be calked into the iron piping with pig lead.

PLASTERING

There is to be no plastering in the basement, but all the walls above are to be finished with three-coat work.

Lathing. All brick walls are furred with terra cotta, on which the plaster is to be placed. All other surfaces are to be

lathed with pine or spruce, only partially seasoned; and wherever these lathed partitions and the brickwork of chimneys or the terra cotta adjoin, expanded-metal or wire-mesh lath are to be placed, extending 8 inches on to each side; as each coat of plaster is placed, all corners are to be cut through from floor to ceiling.

Composition of Plaster. All plastering material is to be freshly burned stone lime, slaked at least two weeks before being mixed with sand; it is to contain hair of the ordinary quality sold for plastering purposes, and sand clean and sharp. The mixing is to be done just prior to its use, and is to be thorough. The hair is to be soaked so as to separate it, and enough must be used, and it must be so mixed that it will not be possible to find any small portions of the mortar in which the hair is not visible.

Application of Plaster. The first coat is to be mixed very rich with lime, using not more than 4 parts of sand to 1 of unslaked lime; it is to be scratched.

The second is to be a thin coat, in which 6 parts of sand may be used to 1 part of unslaked lime; this is not to be applied before the first coat is dry and hard.

The last coat in all cases will be white, a hard finish of lime putty gaged with plaster of Paris. This is to be applied in not less than five days after the first coats appear dry and hard.

The first two coats are to go to the floor back of all baseboards and wainscot, and be brought up to all grounds.

When completed, the work is to be straight and free from discolorations, hair cracks, or lime pits.

NOTE TO STUDENT. No. 3.—See Note No. 1 on page 70, relative to examination of actual masonry work. At this point the student is to follow the directions in No. 1, only applying them to plaster work and materials, and to prepare a 400-word specification of a portion of the work or materials, as explained.

PAINTING, VARNISHING, GLAZING

Painting of Exterior. All exterior woodwork is to be primed, as soon as in place, with raw linseed oil and a very small amount of yellow ocher; and later is to have two additional coats of raw linseed and white lead paint mixed in the proportion of 100 pounds of lead to 5 gallons of oil, colored with such pigments as will produce the single color desired; no more dryer is to be used in each coat than is necessary to insure its drying within 18 hours.

Painting of Interior. All pine woodwork throughout the house, including floors, shall have one coat of white shellac and three coats of paint, mixed as above, and of the colors selected by the Architect. There shall be one color only in each room for finish, and one for floors.

Hardwood Finish. All hardwood except floors is to be filled with a mineral filler, and to have three coats of varnish, the last two rubbed to a dull surface. The varnish is to be of a brand covered by an affidavit from the manufacturers that it contains no resin or petroleum products and that it has at least 17 per cent of copal gums. The varnish must also be of such a character that a film on glass will not dry in less than 48 hours, and when dry, the film is not to be brittle. Four days must elapse between the application of each coat of varnish and the succeeding coat.

All hardwood floors, treads, and risers are to have one coat of hot raw linseed oil and two additional coats of cold raw linseed oil, three days to intervene between each coat and the next.

Glass. All glass is to be at least $\frac{1}{8}$ inch thick and free from all smoke, bubbles, or wavy lines. It is to be set in the sash after priming with white lead, back-puttied, and fastened with points not over 6 inches apart and full-puttied.

PLUMBING AND GAS PIPING

Fixtures. *Bath.* The bathtubs are to be of porcelain, Class A, 5 feet long, glazed all over; with nickel-plated combined waste and bell supply fixture, with compression valves and china indexed handles, and $\frac{3}{4}$-inch iron-size brass supply pipes, nickel-plated. Over the Owner's tub there is to be an $8\frac{1}{2}$-inch tubular shower with hot and cold water through compression bibs with china indexed handles, nickel-plated curtain ring with white duck curtain, and nickel-plated chain and hooks.

Lavatories. The lavatories are to be of vitreous porcelain, 22 by 27 inches, with pedestal; they are to be fitted with combined waste and spout supply fixture, having china indexed handles, and an adjustable trap to wall, nickel-plated.

Water Closets. The water closets are to be of the siphon jet type, with white enameled seat and cover and vitreous porcelain low-down tanks with china lever handles, and brass floor flange with porcelain bolt caps. The flush pipe, vent extension, and seat hinges are to be white enameled.

Wash Trays and Sinks. The wash trays and sinks are to be of porcelain, Class B, white with integral back, porcelain legs and wall supports. The trays shall have $\frac{1}{2}$-inch brass waste plugs with a continuous brass waste pipe to the trap. They are to be supplied with hot and cold water through compression bibs with china indexed side handles. The sinks are to have a $1\frac{1}{2}$-inch outlet strainer and trap to wall, and to be supplied with hot and cold water through compression flanged bibs with china indexed handles. Ash drainboards are to be supplied, as shown. The trays and sinks must be glazed inside and outside.

Hot-Water Boiler. The hot-water boiler is to be of copper, of 60-gallon capacity, and tested to 200 pounds pressure. It is to be connected with the water front of the range, and have supply pipes, pressure regulator, relief valve, and sediment cock complete.

Piping. All cold-water piping is to be of lead, except in the basement, where it is to be of galvanized iron.

All hot-water piping is to be of iron-size brass, semi-annealed, with all fittings of heavy brass. All exposed piping in bathroom and toilet room is to be nickel-plated, in kitchen and laundry, polished brass.

From the end of the water main, now at the front wall, extend a 1¼-inch pipe to where the lead riser leaves the first floor level. This riser is to be 1 inch and to extend to the ceiling of the upper floor. The branch to the basement wash trays, from the 1¼-inch main, is to be ¾-inch, and that to the watercloset tank, ½ inch.

Above the basement, branches to sinks and watercloset tanks are to be ½ inch; to bathtubs and hot-water boiler, ¾ inch; and to lavatories, ½ inch.

Hot water from the boiler at the kitchen range is to be circulated to all fixtures except water closets in pipes of the above sizes.

All lead pipes are to be run on hardwood boards and through floor boxes, and to have tacks not over 2 feet 6 inches apart; where run horizontally, there are to be two brass bands between each pair of tacks, to prevent sagging.

No turn is to be made on a circle of less than 9 inches diameter; pipes are to be so carried as to provide a dead end of not less than 3 feet above the highest branch, and so graded that all will drain through a stop cock and waste cock to be set just inside the basement wall.

Joints. There are to be as few joints as possible in the lead piping; but where they occur, either in connection with lead or brass, the joints are to be wiped; if connections are necessary to iron pipes, brass ferrules, either calked or screwed into the iron pipe, are to be used.

Stop Cocks. Just inside the basement wall, and wherever a branch leaves the main in both hot- and cold-water lines, place stop cocks and waste cocks with a waterway equal to the area of the pipe in which it is placed, and with ¼-inch wastes to waste pipes or sewer. Those in the cellar are to be plain brass; and those above, nickel-plated, with lever handles.

Faucets. All faucets, except for bathtubs, are to be self-closing, of ⅛-inch larger waterway than the pipe supplying them; those in the wash trays and sinks are to be plain brass, those for bowls to be low-down nickel-plated.

The bathtubs shall be equipped with combination, compression bibs closing with the pressure, of the plainest and heaviest stock pattern, with a nozzle and to which a ½-inch hose can be attached.

Traps. Under the set of tubs, each sink, and bathtub, set a 4-inch lead pot trap, 8 inches deep, with a 4-inch brass trap screw in the top, set in an accessible place as near the fixture as possible.

Under each bowl set a nickel-plated trap which cannot be siphoned under any conditions existing in the building, and with no movable parts, but with a trap screw which will permit cleaning,

Soil Pipe and Connections. All soil pipe and fittings are to be of cast iron of the grade known to the trade as "Extra Heavy" —that is, the grade in which a 5-foot length of 4-inch pipe weighs not less than 65 pounds, and is coated outside and inside with asphalt paint. The main line extending from the running trap in the manhole to a point just above the highest fixture, is to be 4-inch; all branches to fixtures are to be of the smallest diameter allowed by the city ordinances, and are to be brought to points as near the fixtures as possible.

Above the highest fixture, a 4-inch wrought-iron fitting is to be calked into the cast-iron hub of the soil pipe, and continued with a 4-inch wrought-iron screw-jointed pipe into the flue for the kitchen range, and thence to top of chimney; but before the wrought pipe enters the flue, a right angle is to be formed in the screw-joint fittings, so that, in case of unequal settlement of any part, the screw joint in the angle will take up the movement.

Back air or vent pipes are to be installed only as required to comply with the city ordinances.

All soil and waste pipes are to be calked with pig lead.

As the details show the location of pipes and fittings required on the plumbing drawings, they are not described here.

All connections from bowls and sinks to traps and waste pipes and also from wash trays are to be of 1½-inch "n.p." brass. From bathtubs the waste pipes are to be 1½-inch "Heavy" lead; and the joints are to be formed as indicated above for water runs.

The waterclosets are to be set on and bolted to brass flanges above the floor, from which a 4-inch lead bend of 8-pound weight is to connect with a brass ferrule calked in the soil pipe.

The flush pipe connection from tank to watercloset is to be nickel-plated brass 2-inch pipe.

In carrying out the entire plumbing system, all pipes are to be run exposed, except where the soil pipe is continued in the flue. There is to be no cutting of timbers; and wherever pipes pass through partitions or floors, collars of the same material as the pipe are to be placed, except that where lead pipes are used, the collars are to be of nickel-plated brass.

Test. After the roughing-in of soil and waste pipe is complete, all outlets below the top are to be stopped, and the entire system is to be filled with water, which is to stand in the pipe without settlement for 10 hours.

Obedience to City Regulations. The requirements of the city ordinances are to be observed; but where this specification requires work or material in addition to that specified by the ordinance, the city regulations are not to be construed as relieving the Contractor from furnishing all that is herein specified; and when the work is completed, it must be in such condition that every fixture and pipe shall perform the functions pertaining thereto in a perfect manner.

Final Tests of Plumbing. It shall, further, be an obligation on the part of the Contractor to make the smoke-and-peppermint test of the entire system, when required, not less than 3 months after the occupancy of the premises; and previous to such tests, there is to be no tightening of unions or other screw joints. Any joints which then are not found to be perfectly tight, are to be opened, and such washers or other appliances placed as in the opinion of the Architect will make a permanent seal.

NOTE TO STUDENT. No. 4.—See Note No. 1 on page 70, relative to examination of actual masonry work. At this point, the student is to follow directions there given, only applying them to plumbing work and materials, and to prepare a 400-word specification of a portion of the work and materials, as explained.

Gas Piping. Inasmuch as the Gas Company lays down full and complete rules governing the sizes of pipes and methods of running them, which must be followed, this portion of the work is not set forth here, further than to require that such rules shall be followed. But in carrying out the work no joist is to be cut more than 1 inch deep, and never more than 8 inches from its bearing.

No vertical stud is to be cut more than 1¼ inches deep, and no vertical supporting timber or pier under any circumstances.

When complete, the system is to be tested, in addition to the Gas Company's test, with 15 pounds air pressure, which must be held for half an hour.

HEATING

The Owner shall furnish, deliver, and set up in the cellar, but without any smoke pipe or steam pipe connections, a cast-iron, sectional, low-pressure steam boiler; and the Contractor is to furnish and place all other necessary material and labor to install the system completely. All radiators are to be of cast-iron. The piping is to be so installed that all steam and condensed water in the same pipe will travel in the same direction, except that one

short connection to radiators may let in steam and take out water, so that only one valve will be required.

All radiator valves are to have unions, so that the radiator can be completely disconnected thereby, and are to be nickel-plated, with wooden handles.

The air valves to radiators shall be of the approved automatic type. All valves other than radiator valves in pipes shall be gate valves, allowing a full opening.

The sizes and positions of all radiators and pipes are shown on drawings Nos. 30, 31, 32, and 33.

The smoke pipe from the boiler is to be of No. 22 gage black iron, with riveted joints.

After the system of steam pipes and radiators is complete, it is to be tested with air pressure to 50 pounds; and the pressure is to stand one hour without showing any drop at the gage.

All radiators are to be bronze-painted; all pipes above basement are to be painted maroon, and all in basement black.

A brick wall is to be placed around the boiler, extending to the floor lining between the joists, leaving a space of at least 2 feet between boiler and wall at all points except in front. Overhead, nail to the joists No. 24 galvanized-iron sheets, above which, between the joists, put 2 inches of mineral wool.

From the chamber thus formed, take IX tin pipes (that is, pipe of tin on iron or steel plates which weighs approximately 9 ounces to a square foot before coating with tin) to the registers indicated on the First Floor Drawing. Each pipe is to have a damper completely closing the entire area. The registers are to have tight-fitting valves and cast-iron borders.

Build the cold-air box of No. 24 galvanized iron, with hinged valve closing the entire area, and with chain and weight competent to hold it in any desired position.

NOTE TO STUDENT. No. 5.—See Note No. 1 on page 70, relative to examination of actual masonry work. At this point the student is to follow the directions in No. 1, only applying them to heating apparatus, etc., and to prepare a 400-word specification of a part of the apparatus.

CLEANING PREMISES

After the work is practically completed, all surplus material and débris are to be removed from the premises; the building swept clean; windows washed; and the finish wiped off, so as to allow a final inspection of all visible points. Any items which are then passed as satisfactory shall be considered as fully complying with the contract requirements, unless there later appear hidden defects which at that time could not be seen.

FORMAL CONTRACTS

Contractors' Bids. Duplicate copies of the specifications given in the preceding pages are sent to various contractors and bids asked for. After proper analysis of the specifications and drawings, each contractor submits a sealed bid, preferably according to the following form:

PROPOSAL SHEET

....., the undersigned, hereby proposes to construct a dwelling for .....
in strict accordance with drawings numbered.....
and the foregoing specifications for the sum of.....
.....$.....

If light colored sand stone or lime stone is substituted for all face brick and ornamental terra cotta following the same outlines, add - - - - - - - - - - - - $.....

If two months more time is allowed for the construction, deduct - - - - - - - - - - - - - - - - - $.....

If in the upper stories plain oak is substituted for painted pine, add - - - - - - - - - - - - - - - - $.....

Signed.....

Award of Contract. After the completion of the drawings and specifications, and due consideration of the bids received from the contractors who are asked to figure on the work, it is customary to award a contract—that is, to enter into an agreement for carrying out the work; and an instrument is drawn for the signature of both the owner and the contractor, setting forth their legal relations. Inasmuch as a contract between two parties is an agreement to do a certain specific thing, it is evident that the principal part of the contract, or the basis therefor, consists of the drawings and specification, in which is the full and complete description of the specific thing to be done. Hence, in the preceding text, the point that every requirement and condition should be clearly set forth, has been emphasized; for, however strong the formal contract may be, if it has no specific basis, it is of no value. Therefore, from a legal standpoint, emphasis is again placed on the necessity for a clear and unambiguous statement in the specification, of just what is to be done.

The *formal contract* is not drawn till after the award of the work; but separation in time does not change the fact that it is only a continuation of the specification; it is the completion of the latter, and it should, in short, clear terms, set forth the final arrangement.

As the province of the specification is to set forth and explain what is not included in the province of the drawings, the formal contract is to set forth such final conditions as the specification was not able to cover.

GENERAL CONTRACTS

Alterations in Work. There are certain conditions likely to prevail in carrying out the work, which may in a very material way affect the operation of the contract, and possibly destroy its force, notwithstanding the fact that its basis is sound. As the contract is an agreement to do a certain specific thing, it follows, that, if any change is made in any of the matter which goes to make up that specific thing so that some other specific thing is substituted, the terms of the contract are not filled; and such a change, unless properly guarded, can be made the basis of refusal on the part of either the owner or the builder to abide by all the conditions covered by the contract. Questions of this description are among the most serious which arise in general architectural practice.

As buildings progress, the owner and often the architect see items which, if changed, would improve the result; and as the departure from the specific thing contracted for appears slight, the builder is, in a general way, either requested or directed to make the change. Also, in the progress of the work, the builder often finds it possible for him to make better arrangements for materials, etc., by making substitution, and, considering the change of little moment, he proceeds to make it.

In the first of the cases above cited, the owner or the architect is surprised when he finds that modifications made are the basis for an extra charge of some magnitude; and that they are also used as an excuse (and it is generally valid) for several days' delay in the completion of the work.

In the second case, the builder is surprised to find his substitution the basis of a demand that he make a material deduction from the contract price.

In either case, the architect is blamed by both parties—and often justly so—for allowing matters to drift into the existing conditions; and it is not unusual for the owner and builder to get together and settle their differences, without changing their opinion of the architect.

Therefore, after the signing of the contract, it should be the special province of the architect to see that as few changes as possible are made; and, when it is advisable to make changes, to be certain that all the conditions affected thereby are fully understood, and that such understanding is expressed in writing signed by both parties.

It is not the intention here to intimate that desirable changes should be abandoned in order to avoid complicating the contract situation, because there is no work in which improvements cannot be made as it progresses; but emphasis is laid on the suggestions that such changes should be as few as possible, and should never be allowed at all unless there is a distinct advantage gained to the *owner,* and that, in consenting to any changes, the case should be put in such formal shape that there can be no later misunderstanding.

Prompt Preparation of Detail Drawings. As the question of time is generally important to the owner, the architect should see that all detail drawings are furnished within the specified time, as it is unreasonable to expect the builder to complete the work on time if he is delayed in the receipt of the drawings. A delay is generally a sufficient excuse for extension of the contract time for completing the work. Special care should be taken that the modification in the details be not of such a character as can be used as a basis for demands for extra compensation beyond contract prices.

Agreement between Owner and Builder. Under the ordinary conditions that prevail in private practice in work that is not of great magnitude, a simple document is all that is necessary to set forth the final relations of owner and builder, in form somewhat as follows:

FORM OF AGREEMENT BETWEEN OWNER AND BUILDER

AN AGREEMENT entered into this 15th day of March, 1916, by and between....., of Chicago, Owner, party of the first part, and....., also of Chicago, Builder, party of the second part:

WITNESSETH: That the said party of the second part, for and in consideration of the sum of Five Thousand ($5,000.00) Dollars, in payments as set forth in the specification, agrees to construct a city dwelling for the said party of the first part, at the corner of.....Ave. and.....St., city of Chicago, in accordance with drawings numbered.....and specifications, all prepared therefor by....., Architect.

Which drawings and specifications are a part of and the basis of this agreement.

IN CONSIDERATION of the foregoing, the said party of the first part agrees to pay to the said party of the second part the full sum of Five Thousand ($5,000.00) Dollars, in payments and under conditions as fully set forth in the specification.

In witness of the foregoing, the parties aforesaid here set their hands and seals to this and one other instrument of like tenor and date, this..... day of ....., 1916.

....., Owner (Seal)

....., Builder (Seal)

In presence of:

.....

.....

Should changes be necessary, a supplementary agreement in the following form should be prepared for the signature of both parties:

WHEREAS: ....., Owner, did, on the fifteenth day of March, 1916, enter into an agreement with....., Builder, for the erection of a dwelling in accordance with drawings and specification prepared therefor by....., Architect, as fully set forth in such agreement; and

WHEREAS: it is the desire of said....., Owner, to make certain changes as fully set forth as follows:

.....

.....

The said....., Builder, agrees to make such changes and make all necessary modifications in the work necessarily incident thereto, for the sum of One Hundred ($100.00) Dollars, as an addition to the original contract price for the work, it being understood that no additional time is to be required in the completion of the work on account of these changes.

And the said....., Owner, agrees to pay the additional sum of One Hundred ($100.00) Dollars on account of these changes.

In witness of the foregoing, the parties aforesaid have set their hands and seals to this and one other instrument of like tenor and date this..... day of....., 1916.

....., Owner (Seal)
....., Builder (Seal)

In presence of:

.....
.....

The above agreement has been duly noted by me,

....., Architect

Architect's Monthly Reports. As the work progresses, it will be necessary for the architect each month to make an estimate of the value of the labor and materials satisfactorily in place, and to issue to the contractor a certificate for presentation to the owner. A certificate not only serves its purpose of notifying the owner of the amount due, but also furnishes him with a statement of the account to date. It is very desirable that both owner and contractor shall each month see, understand, and sign a clear statement of the conditions existing under the contract; for this closes up all matters which if allowed to drift, might cause serious misunderstanding. The form of certificate is given below.

Certificate No. 2.

CHICAGO, ILLINOIS
May 1, 1916

THIS certifies that....., Contractor, under his agreement, dated March 15, 1916, with....., to construct a dwelling at the corner of.....Ave. and.....St., city of Chicago, is entitled to a payment in amount Twelve Hundred Dollars ($1,200.00) under the terms of said agreement in accordance with the following statement of the account:

Contract price	$5,000.00
Extra No. 1, dated April 3, 1916	100.00
Extra No. 2, dated April 18, 1916	125.00
Total of contract and extras to date	$5,225.00
Value of work and materials satisfactorily in place at this date	
Retained percentage 10%	$ 240.00
Certificate No. 1, April 1, 1916	960.00
Certificate No. 2, May 1, 1916	1,200.00
Total value of work in place on this date	$2,400.00
Total balance unpaid under this contract	$2,825.00

To....., Owner. ....., Architect.

May 3, 1916.

RECEIVED from....., Owner, the sum of Twelve Hundred Dollars ($1,200.00), and I acknowledge that the above statement of the account is complete and correct.

....., Contractor.

RECEIPT FOR INSURANCE POLICIES

(To be detached and delivered to Contractor after signing)

RECEIVED of....., Contractor, fire insurance policies as follows: .....in total amount $2,600.00, issued as required by agreement dated March 15, 1916, for the erection of a dwelling for me at the corner of.....Ave. and.....St.

....., Owner.

Contracts That Require Bonds. In all the foregoing relative to formal contracts, consideration has been given only to such cases as would come up in an ordinary private practice, where it is taken for granted that the relations of parties with one another are such that all that is necessary to insure a satisfactory completion of all agreements is a definite understanding of exactly what is to be furnished and done by each of the contracting parties. No contracts can be drawn, or specifications written, which prevent either party from bringing suit against the other if he so desires.

The question is entirely different in the case of formal contracts for public or corporation work requiring bonds where, on account of the impersonal nature of the owner, it is impossible to adapt procedure to the varying conditions that arise. It is entirely outside the province of the architect to attempt to arrange details of a legal nature in such cases. The liability of a bondsman is very peculiar, and he can be relieved therefrom because of even very small departures from the agreement. Thus changes in the work or material, changes in the dates or manner of payment, changes in time of completion of the work, etc., can be set up (and generally with success) as reasons why the obligations under the bond should be set aside.

As a general thing, bonds are now furnished by large corporations who employ the best of legal talent to dispute, on any ground, their liability should they be called on; and it is unreasonable for an architect to attempt to protect his patron's interest under such circumstances. Therefore, in cases of this nature, the attorney

representing the public body or the corporation for which the work is to be done, should draw the formal contract and bond, and supervise their execution. Any action during the progress of the work which could in any way affect the specific obligations of either party, should be passed on by such attorney; and, in case of any change, he will obtain a formal consent of the sureties on the bond, before its final ratification.

GOVERNMENT CONTRACTS

It is not generally known how extensive are the building operations of the Treasury Department of the United States, or how greatly its demands for material and labor influence the market; nor do many contractors or material men know much about the nature of the contracts to be awarded. There is, besides, a kind of superstition that such contracts are so bound up in red tape that it is wise for contractors and men with good material to keep out of this market. It is the object of this section to show the amount of work which is under the control of the Treasury Department; to indicate its general nature and the conditions under which contracts are let and the work executed, and which govern the furnishing of materials; and to explain the nature of the formal contract and in what respects it differs from those usually required between individuals.

Government work is not all red tape. In fact, when the reasons for certain fixed lines of action are understood, the red tape appears in the light of necessary business machinery, which, if more frequently applied with discretion to private enterprises, would assist in producing results far in advance of the average now obtained.

Number and Value of Government Building Contracts. There are at times under contract, wholly or in part, or awaiting contracts which will usually be awarded within two years, nearly two hundred fifty buildings, the cost limit of which, including sites, would be fixed by Congress at approximately $40,000,000. Placing the cost of sites at about 20 per cent of the total, it will appear that the buildings will require in material and labor over $30,000,000. At the rate at which work is generally carried on, the disbursements involved through the different channels would be from $600,000 to $1,000,000 *a month.* While there are many corporations in the

world disbursing an equal sum for materials and labor required in industrial enterprises, there is probably none where such large sums are disbursed through general channels open to so many branches of industry.

Character of Buildings and Their Fittings. The buildings under the control of the Treasury Department are for the use of the civil branches of the Government, such as Postoffices, Courts, Customs, Internal Revenue, Marine Hospitals, and Quarantine Stations. Such buildings as the Capitol, the Library of Congress, and the executive buildings of the different Departments at Washington, are not under the control of the Treasury Department nor built by it; neither are forts or other Army or Navy buildings, or United States jails.

Many of the buildings under the Treasury Department are very large and expensive, the New York Custom House and the Chicago and San Francisco postoffices being buildings of this type. The larger number, however, are of moderate size, ranging from structures of 40 feet by 80 feet outside dimensions and one story high, to buildings of three times that area and three stories high, costing complete, with heating apparatus, etc., from $35,000 to $175,000 each.

The large majority are of fireproof construction and classic design, with interior finish of hardwood and marble where the funds permit. The best of materials and appliances are used throughout, as it is inadvisable and almost impracticable in public buildings of this character to exercise the many economies which prevail in private building.

The interiors are fitted with the best of modern appliances and conveniences; plumbing is extensive and of the most modern kind; the toilet rooms for postoffice carriers are supplied not only with the usual appliances, but often with shower-baths; and no woodwork, either in floors or in finish, is allowed. Throughout the building, small private toilet rooms are provided for the more prominent officials; and in many, especially in the south, bathtubs are supplied. The heating, ventilating, and electric work are, in their way, equally complete.

The buildings in the larger cities where the Railway Mail Service men change, have dormitories for the accommodation of from

ten to seventy-five men. In the postoffice proper are galleries with openings commanding every corner accessible to the men, from which inspectors can watch for days, without arousing suspicion, any person suspected of pillaging the mails.

There is always a large "swing room" for carriers when off duty, where they have games, boxing gloves, and occasionally a billiard table for recreation.

In the larger postoffice buildings there are the most elaborate mechanical equipments, engines, boilers, electric generators, elevators, mail-carrying and handling devices, sweeping machinery, etc.

From the foregoing it is evident that there are few lines in the building industries which should not be interested in the erection and furnishing of these many buildings.

Building Conditions. It is a matter of interest to a very large body of contractors, subcontractors, artisans of all callings, and material men, and manufacturers, how the Department builds, and in what ways it differs from the average investor in its building operations and contracts.

There is a prevalent idea that mystery surrounds the act of securing the whole or any part of a government contract—that one must be on the inside and know how to pull the wires. This feeling arises probably from the facts that the Government as an employer and owner is a very different affair to deal with from a personal owner; and, because of such difference, and because of the magnitude of the varied branches of work, rendering it necessary to have some fixed and unyielding rules and regulations to which all doing business with the Government must comply, the great mass of people who should be interested are likely to think that this is all red tape, and that they cannot get near any of this work.

Exactness and Rigidity of Contract. When the owner and the contractor in ordinary practice make an agreement, it is always modified by the personal conditions and qualities of each, so that the conditions and terms frequently differ materially in instances of work of the same character. With the Department, however, this cannot be. The Department has fixed policies and rules, and is hedged about by law in such a way that it must be unyielding at all points; it cannot adapt the work to the conditions of the con-

tractor; it can take no chances; and anyone seeking to do business with the Department must lay aside all personal ideas of methods, and must seek from the first to get into the line of the Department's method and requirements, even if these appear to be without reason. The contractor who imagines that he can take a contract, and can afterward have its lines modified to suit his own methods, which he may honestly believe to be better than the requirements of the Department, is not only bound to be disappointed, but is certain to lose a round sum before final settlement.

When bids are asked for the construction of a building, the drawings and specifications are so prepared that the bidder is given notice relative to every requirement; nothing is taken for granted; it is fully set forth to what extent he is to be responsible for the completion of the work, and he is shown all details leading up to such completion. How and when each payment shall be made, is fully explained. Many of these requirements are unusual; the builder may not, and probably does not, understand why they are inserted; but that is really none of his business; the requirement is plainly stated, and if he wants to put in a bid, he has but to figure just what the cost of the apparently useless requirements will be, and to add such amount to his bid.

The conditions which govern Treasury contracts are the result of the experience of many years; and if a greater proportion of private owners and contractors for private work would adopt similarly exact methods in their operations, their work would be attended with much fewer annoyances and much less friction. The Department is just as rigid in not permitting a contractor to furnish something for nothing, as it is in not permitting him to substitute a poorer article than that required by the contract. Should the contractor under any circumstances make a substitution, he is never safe. The superintendent on the work may pass it; but the contractor never knows when some traveling inspector or other official may arrive and detect the change. In that case, the superintendent, as well as the contractor, receives severe censure, and the contractor has either to rectify the trouble or to consent to a deduction of a good round sum, which usually represents several times the difference in value between the material furnished and that required.

Final Authority in Disputes. It is fully set forth in the specification that, in case of dispute regarding what is required or regarding the value of extra work, either as an addition or as a deduction, the decision of the supervising architect is to be final; and this means more than such clauses in private specifications, for the Department cannot be sued, and, in case the contractor objects to the ruling and stops work, the Department has the power to abrogate the contract and to finish the work at the expense of the sureties on the contractor's bond. Later the contractor can bring a suit in the Court of Claims; but it is very rarely that any substantial change is made in the original rulings. This rather autocratic power appears one-sided, and at first thought unfair; and, because of such appearance, it is never exercised except under extreme conditions, after every effort at reasonable settlement has failed; and then the decisions are such that, as above stated, the Court of Claims rarely reverses them to any extent.

This power is necessary for the Government; otherwise the Department would be at all times subject to inroads and impositions which would make progress impossible.

Rights of Subcontractors and Material Men. The subcontractor and material man has no right of lien; but he has a right, after a certain lapse of time, to bring suit against the contractor; moreover the bond required by the Government, equal to one-half of the contract price, is also for his benefit, so that he has the same protection under the bond as has the Department. Upon application, certified copies of all contracts and bonds are furnished for his use by the Department, free. But the Department is under no obligation, nor has it any right, to withhold payments from the contractor at the request or demand of unpaid creditors.

The relations of subcontractors and material men at the Department are peculiar in that they cannot in any way be recognized in a business connection; they have no more connection with the Department than a factory which makes the shoe sold by a dealer has with the customer. The contractor is the only business man known or recognized; all business of whatever nature must come under his signature. A subcontractor can get no information or directions from the Department's representative. If it were otherwise, the contractor would have just cause for

complaints relative to the Government's interference with his business.

Provisions for Competitive Bids. Many years ago a Departmental order forbade the requirement of any particular item which might limit competition, or the mention of any particular material or appliance, "or its equal"; as a consequence, there must be inserted in the specification such descriptions as will require appliances or materials which can be had through competition and which will accomplish the ends required. The contractor is at liberty to obtain his samples for approval in any market he desires; but when such samples are approved, it is a very difficult matter to have a change authorized; were it otherwise, the Department would be constantly annoyed and delayed in its work by contractors changing their minds relative to the parties with whom they wish to deal.

It is often urged by persons controlling some new and special appliance, that it is not good business for the Department to refuse to specify an article having all the desirable points which it is evident, they maintain, belong to the particular article controlled by them. If this idea governed, the office of the supervising architect would be overwhelmed by enthusiastic men with material and appliances of very doubtful value, the claims of which would be generally urged with a strenuousness in direct proportion to their worthlessness.

Experience has also shown that where competition relative to items entering into work has not existed, the persons controlling the appliances used rarely resist the temptation to charge abnormal prices. This results in the contractor seeking relief at the Department and asking to be permitted to make a substitution; if his request is granted, the higher bidders at once set up the claim that their figures were based on the specified requirements, and if they had known that such were not to be enforced their bid would have been low enough to capture the contract.

Changes in Contract. After a contract is once made, no one other than the Secretary of the Treasury, or, under certain circumstances, an Assistant Secretary, has the authority to make a change, no matter how small. The superintendent on the work can allow no variations; nor has even the supervising architect himself any authority to make a change. For instance, two rough coats of

plaster are required back of a certain wainscot, but it is found advisable to omit the second; the area is small, and the difference in expense nothing. But the superintendent must obtain from the contractor a proposal to omit this coat without expense to the Government; and after this proposal has gone through the different divisions of the supervising architect's office for note, comment, and recommendation, the Assistant Secretary accepts the proposal in regular form as a public exigency, and with the understanding that it is not to affect the time for completion, or the obligation of the sureties on the bond, etc. If it were otherwise, the superintendent would be constantly harassed by requests and arguments for changes; and if he permitted changes, the worst of motives would be imputed to him.

Justice in Government's Methods. So thorough is the system in the Department, that there is no detail too small for the fullest consideration. There is probably no architect's office elsewhere in the world where all details receive such attention; and there are few transactions of any nature occurring within recent years, of which all details cannot be obtained by any official in the office in less than ten minutes.

When the red tape of the Department is considered from various standpoints, and the results reviewed, it should inspire more respect than is usually accorded to it; and the man who is seeking contracts or subcontracts should first of all get into the spirit of the business methods of the Department, make his bid to cover all its requirements, and, if he gets the contract, use his best efforts to live up to the letter of every requirement. Such methods will bring success; carelessness will bring failure.

It is often stated that such and such persons have the "inside track" with Departmental work, and that there is no use bidding against them. This is in a sense true; but in all such cases it will be found that that "inside track" was laid by the contractor getting in line with the Department's methods and doing business as thereby required; and the way is open for any other man to lay for himself such an *"inside track."*

Methods of Soliciting Bids. There is a prevalent impression that it requires some special effort to have an opportunity to figure on Department work. There could, however, be no greater mistake,

as every effort is made by the supervising architect to obtain the best competition. For every building, from forty to sixty sets of drawings and specifications are printed and sent without charge (being carried both ways free) to any *general contractor* who makes an application. In a very few instances a certified cheque is required, the proceeds of which are returned upon the receipt of the drawings, etc., in the office. Subcontractors and material men cannot be supplied with drawings and specifications, as it is impracticable to make a sufficient number of sets, and for the further reason that it is desired that subcontractors and material men shall get all the information on which they base their bids from their principals, thus avoiding the danger of differences of opinion that might arise relative to the scope of the sub-bids.

When bids are wanted, the work is advertised for from four to seven weeks, in representative technical journals throughout the country in the general section in which the work is to be done, and in the local papers of the town or city in which the building is to be erected. Notices as news items are sent to a very large line of trade papers, and also to contractors within a few hundred miles of the city whose addresses are available; but such notices are discontinued if the party addressed does not submit a bid after notices of several buildings have been sent.

Many material men send in requests that their specialties be required, and when they find that that cannot be done, they drop all interest; whereas, if they followed up the matter, ascertained to whom the contract was awarded, and endeavored to arrange to sell any materials handled by them required under the contract, they would often obtain profitable contracts.

Specimen Contract. In order that the exact nature of the form which has to be signed by parties to whom contracts for Treasury buildings are awarded may be seen, a specimen contract is herewith reproduced, with occasional notes in smaller type to explain its provisions. The form of bond is also printed; but, as this varies little from that used in private contracts, no notes in explanation of the provisions of the bond will be found necessary.

CONTRACT

BETWEEN THE

UNITED STATES OF AMERICA

AND

JOHN DOE

WHEREAS, By advertisement, duly made and published according to law, proposals were asked for furnishing all of the labor and materials for the work herein provided for; and

WHEREAS, The proposal of JOHN DOE..... furnished in response thereto, was duly accepted, as hereinafter stated, on condition that he execute a contract in accordance with the terms of said bid.....

NOTE.—The *practical award* of the contract is a letter written by the Assistant Secretary of the Treasury (under written authority of the Secretary) to the successful bidder, accepting the bid and stating the principal conditions which are to govern—such as the price to be paid, time for completion—approving such appliances as have in the proposal sheet been offered for carrying out the contract (provided such are satisfactory), and settling the amount of bond to be furnished. This letter, referred to below, is attached to, and made a part of, the formal contract.

NOW, THEREFORE, THIS AGREEMENT, made and entered into by and between....., Secretary of the Treasury, for and in behalf of the United States of America, of the first part, and John Doe,
.....
.....
....., of the second part,

WITNESSETH: That the party of the second part, for the consideration hereinafter mentioned, covenants and agrees to and with the party of the first part to furnish all of the labor and materials and do and perform all the work required.....
.....
.....
.....
in strict and full accordance with the requirements of drawings numbered
.....
.....
.....
and such other detail drawings as may be furnished to the party of the second part by the Supervising Architect of the United States Treasury Department; the advertisement for proposals, dated..... 190 ; the specification for the work; the proposal dated..... 190 , addressed to the said Supervising Architect by the said party of the second part; and letter dated.....190, addressed to the said party of the second part by.....
.....Assistant Secretary of the Treasury, accepting said proposal;
.....
.....

(2)

NOTE.—The proposal often covers several pages. First the lump sum price is stated for the entire work; then follow many *Alternates*—that is, the amount the bidder will add or deduct provided certain materials are substituted for those required by the straight bid—as, for instance, the amount to be deducted for "Alternate A," substituting brick for all plain surfaces of the

Superstructure above 1st floor line ..... $.....

After the alternates, *unit prices* are given. Thus:

Price per thousand for common brick in place.....$.....

After this are lists of appliances to be used in the work. Thus:

Name of boiler proposed to be used.....

Number of square feet of grate surfaces..... .....

Etc., etc.

a true and correct copy of each of which said papers is attached hereto and forms a part of this contract; and which said numbered drawings, bearing the signature of the said Supervising Architect and the signature of the said party of the second part, are on file in the Office of the Supervising Architect of the United States Treasury Department, and are hereby made part of this contract.

And the said party of the second part further covenants and agrees that the work herein agreed to be performed shall be commenced promptly upon receipt of notice of the approval of the bond hereto attached, and that the same shall be carried on in such order and at such times and seasons, and with such force as shall from time to time be directed or prescribed by the Supervising Architect or his representative, and that the same shall be completed in all its parts within.....

.....

from the date of the approval of said bond hereto attached; that all materials used shall be of the very best quality of their respective kinds; that all the work performed shall be executed in the most skilful and workmanlike manner, and that both the materials used and the work performed shall be in every respect to the entire and complete satisfaction of the Supervising Architect.

And the said party of the second part expressly covenants and agrees that the bond hereto attached shall be security, also, for the satisfactory performance and fulfilment of all the guarantees set forth in or required by said specification.

.....

.....

NOTE.—No official has any right to permit a Contractor to do any work under the contract until the bond has been formally approved.

It is expressly convenanted and agreed by and between the parties hereto that time is and shall be considered as of the essence of the contract on the part of the party of the second part, and in the event that the said party of the second part shall fail in the due performance of the entire work to be performed under this contract, by and at the time herein mentioned or referred to, the said party of the second part shall pay unto the party of the first part, as and for liquidated damages, and not as a penalty, the sum of.....dollars for each and every day the said party of the second part shall be in default, which

(3)

said sum of.....dollars per day, in view of the difficulty of estimating such damages with exactness, is hereby expressly fixed, estimated, computed, determined, and agreed upon as the damages which will be suffered by the party of the first part by reason of such default, and it is understood and agreed by the parties to this contract that the liquidated damages hereinbefore mentioned are in lieu of the actual damages arising from such breach of this contract; which said sum the said party of the first part shall have the right to deduct from any moneys in its hands otherwise due, or to become due, to the said party of the second part, or to sue for and recover compensation or damages for the nonperformance of this contract at the time or times herein stipulated or provided for.

NOTE.—The question of *actual* damages is always a very difficult one to settle, and generally involves a lawsuit; therefore the contract states the amount of *liquidated* damages, or the amount settled and fixed in advance by both parties to be paid by the Contractor in case of default. While this amount is rarely less than $20.00 a day, with an average of about $40.00, the Secretary of the Treasury is empowered by Congress to remit so much as will reduce such sum to one that in his judgment is right; and as a matter of fact, it is usual to assess only such an amount as will cover the actual expense of maintaining a Superintendent on the ground, and any items of rent, etc., and additional inspections for which the Department has actually to pay on account of the failure to complete within contract time.

The party of the second part further covenants and agrees to hold and save the United States, its officers, agents, servants, and employees, harmless from and against all and every demand, or demands, of any nature or kind, for, or on account of, the use of any patented invention, article, or appliance, included in the materials hereby agreed to be furnished under this contract.

It is further covenanted and agreed by and between the parties hereto that the said party of the second part will, without expense to the United States, comply with all the municipal building ordinances and regulations, in so far as the same are binding upon the United States, and obtain all required licenses and permits, and be responsible for all damages to person or property which may occur in connection with the prosecution of the work; that all work called for by the drawings and specifications, though every item be not particularly shown on the first or mentioned in the second, shall be executed and performed as though such work were particularly shown and mentioned in each, respectively, unless otherwise specifically provided; that all materials and work furnished shall be subject to the approval of the said Supervising Architect; and that said party of the second part shall be responsible for the proper care and protection of all materials delivered and work performed by said party of the second part until the completion and final acceptance of same.

NOTE.—Municipal laws are binding on the Government to a very limited extent, and only outside of the lot line; the land, when bought by the Government, not only becomes its property, but it is, by such sale, *ceded* back to the United States, so that the land occupied by the public building is no longer a portion of the State, and the State or City has no more authority over it than it has over the District of Columbia.

Cases sometimes occur when some city official attempts to show authority, as in one case where a permit to enter the sewer was denied until some minor useless demand

(4)

relative to the plumbing was complied with. The official had a perfect right to refuse the permit as the sewer was in the street; but after the Department had decided not to turn on the water, and to leave all plumbing fixtures unusable, the official soon found it better policy to allow the connection. This policy is always followed by the Government, as the practice of the Supervising Architect's office in all matters of this sort is the best, and is generally far better than that followed by many municipal laws.

Inside the lot lines, municipal and state authority do not exist, except for minor police regulations.

It is further covenanted and agreed by and between the parties hereto that the said party of the second part will make any omissions from, additions to, or changes in, the work or materials herein provided for whenever required by said party of the first part, the valuation of such work and materials to be determined on the basis of the contract unit of value of material and work referred to, or, in the absence of such unit of value, on prevailing market rates, which market rates, in case of dispute, are to be determined by the said Supervising Architect, whose decision with reference thereto shall be binding upon both parties; and that no claim for damages, on account of such changes or for anticipated profits, shall be made or allowed.

It is further covenanted and agreed that no claim for compensation for any extra materials or work is to be made or allowed, unless the same be specifically agreed upon in writing or directed in writing by the party of the first part; and that no addition to, omission from, or changes in the work or materials herein specifically provided for shall make void or affect the other provisions or covenants of this contract, but the difference in the cost thereby occasioned, as the case may be, shall be added to or deducted from the amount of the contract; and, in the absence of an express agreement or provision to the contrary, no addition to, or omission from, or changes in the work or materials herein specifically provided for shall be construed to extend the time fixed herein for the final completion of the work.

NOTE.—The somewhat arbitrary power referred to in the foregoing, is, as a matter of fact, rarely exercised; and when exercised, the greatest care is taken to make the amount such that it cannot be questioned. Sometimes Contractors imagine that, having the contract, they can demand for extras an exorbitant price, and they would be successful in many cases but for this saving clause.

It is further covenanted and agreed by and between the parties hereto that all materials furnished and work done under this contract shall be subject to the inspection of the Supervising Architect, the superintendent of the building, and of other inspectors appointed by the said party of the first part, with the right to reject any and all work or material not in accordance with this contract; and the decision of said Supervising Architect as to quality and quantity shall be final. And it is further covenanted and agreed by and between the parties hereto that said party of the second part will without expense to the United States, within a reasonable time to be specified by the Supervising Architect, remedy or remove any defective or unsatisfactory material or work; and that, in the event of the failure of the party of the second part immediately to proceed and faithfully continue so to do said party

(5)

of the first part may have the same done and charge the cost thereof to the account of said party of the second part.

It is further covenanted and agreed by and between the parties hereto that until final inspection and acceptance of, and payment for, all of the material and work herein provided for, no prior inspection, payment, or act is to be construed as a waiver of the right of the party of the first part to reject any defective work or material or to require the fulfilment of any of the terms of the contract.

It is further covenanted and agreed that the party of the first part shall have the right to require that any particular portion of the work herein provided for shall be completed within such time as may be hereafter definitely specified by the said party of the first part in written notice to the said party of the second part; and that should the said party of the second part fail to complete such particular portion of the work within the time so specified, or fail to complete the entire work contemplated by this contract within the time or times herein stipulated or provided for; or fail to prosecute said work with such diligence as in the judgment of the party of the first part will insure the completion of the said work within the time hereinbefore provided, the said party of the first part may withhold all payments for work in place until final completion and acceptance of same, and is authorized and empowered, after eight days' due notice thereof in writing, served personally upon or left at the shop, office, or usual place of abode, or with the agent of the said party of the second part, and the said party of the second part having failed to take such action within the said eight days as will, in the judgment of the said party of the first part, remedy the default for which said notice was given, to take possession of the said work in whole or in part and of all machinery and tools employed thereon and all materials belonging to the said party of the second part delivered on the site, and, at the expense of said party of the second part, to complete or have completed the said work, and to supply or have supplied the labor, materials, and tools, of whatever character necessary to be purchased or supplied by reason of the default of the said party of the second part; in which event the said party of the second part shall be further liable for any damage incurred through such default and any and all other breaches of this contract.

It is further covenanted and agreed that the said party of the first part shall have the right of suspending the whole or any part of the work herein contracted to be done, whenever, in the opinion of the Supervising Architect, it may be necessary for the purposes or advantage of the work, and upon such occasion or occasions the said party of the second part shall, without expense to the United States, properly cover over, secure, and protect such of the work as may be liable to sustain injury from the weather, or otherwise; provided that for all such suspensions and other delays caused by the said party of the first part the party of the second part shall be allowed one day additional to the time herein stated, for each and every day of such delays so caused, in the completion of the contract, the same to be ascertained by the Super-

(6)

vising Architect; provided, that no claim shall be made or allowed to the said party of the second part for any damages which may arise out of any delay caused by the said party of the first part.

And the said party of the first part, acting for and in behalf of the United States, covenants and agrees to pay, or cause to be paid, unto the said party of the second part, or to the heirs, executors, administrators, or successors, of the said party of the second part, in lawful money of the United States, in consideration of the herein recited covenants and agreements made by the party of the second part, the sum of.....

.....

.....

And the party of the first part covenants and agrees that payments will be made in the following manner, viz: ninety per cent of the value of the work executed and actually in place, to the satisfaction of the party of the first part, will be paid from time to time as the work progresses (the said value to be ascertained by the party of the first part), and ten per cent thereof will be retained until the completion of the entire work, and the approval and acceptance of the same by the party of the first part, which amount shall be forfeited by said party of the second part in the event of the nonfulfilment of this contract; it being expressly covenanted and agreed that said forfeiture shall not relieve the party of the second part from liability to the party of the first part for any and all damages sustained by reason of any breach of this contract; provided, however, that no payment hereunder shall be due to the said party of the second part until every part of the work to the point of advancement reached—on account of which payment is claimed—shall be found to be satisfactorily supplied and executed in every particular and any and all defects therein remedied to the entire satisfaction of the said party of the first part.

It is an express condition of this contract that no Member of Congress, or other person whose name is not at this time disclosed, shall be admitted to any share in this contract, or to any benefit to arise therefrom; and it is further covenanted and agreed that this contract shall not be assigned.

IN WITNESS WHEREOF, The parties hereto have hereunto subscribed their names this.....day of.....A.D. 190 .

.....

.....

.....

.....

.....

.....

.....

.....

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.....

.....

All erasures, alterations, and interlineations to be noted here before execution.

(7)

We hereby certify that this contract and bond have been correctly prepared and compared:

.....
Chief of the Law and Records Division.

.....
Superintendent of the Computing Division.

.....
Secretary of the Treasury.

Witnesses to the signature of the Contractor:

Two witnesses.

.....

.....

.....
Contractor.

Place corporate seal here.

NOTE.—The above relates to one of the most vexing questions both to the Contractor and to the Department, which is encountered. When a Contractor gets hopelessly in default, it is as bad for him as for the Department to try to push through In such cases he is credited with the full value of all labor and materials on the ground; but for all additional items to complete the work covered by the contract, the sureties on his bond have to pay. Usually the bondsmen take the contract to finish the work; and in most cases, so far as the Department is concerned, no litigation follows.

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(1)

BOND

KNOW ALL MEN BY THESE PRESENTS, That we,.....
.....
.....
of the City of....., County of....., and
State of....., principal , and.....
.....
.....
of the City of....., County of....., and
State of....., and.....
of the City of....., County of....., and
State of....., suret....., are held and firmly bound unto the
United States of America in the sum of.....dollars
($.....), lawful money of the United States, for the payment of
which, well and truly to be made to the United States, we bind ourselves,
our heirs, executors, administrators, successors, and assigns, jointly and
severally, firmly by these presents.....

Sealed with our seals and dated this.....day of ....., A.D. 190 .

THE CONDITION OF THE ABOVE OBLIGATION IS SUCH, That whereas the
said.....ha.. entered into a certain contract,
hereto attached, with..... .....Secretary of the
Treasury, acting for and in behalf of the United States, bearing date the
.....day of....., A.D. 190 : *Now*, if
the said.....
.....
shall well and truly fulfil all the covenants and conditions of said contract,

(2)

and shall perform all the undertakings therein stipulated by..... to be performed, and shall well and truly comply with and fulfil the conditions of, and perform all of the work and furnish all the labor and materials required by, any and all changes in, or additions to, or omissions from, said contract which may hereafter be made, and shall perform all the undertakings stipulated by.....to be performed in any and all such changes in, or additions thereto, notice thereof to the said suret..... being hereby waived, and shall promptly make payment to all persons supplying.....labor or materials in the prosecution of the work contemplated by said contract, then this obligation to be void; otherwise, to remain in full force and virtue.....

IN TESTIMONY WHEREOF, The said.....

.....

....., principal , and.....

.....

and....., suret.....

have hereunto subscribed their hands and affixed their seals the day first above written.....

Signed, sealed, and delivered in presence of.....

Two witnesses to each signature.

.....

.....

.....

.....

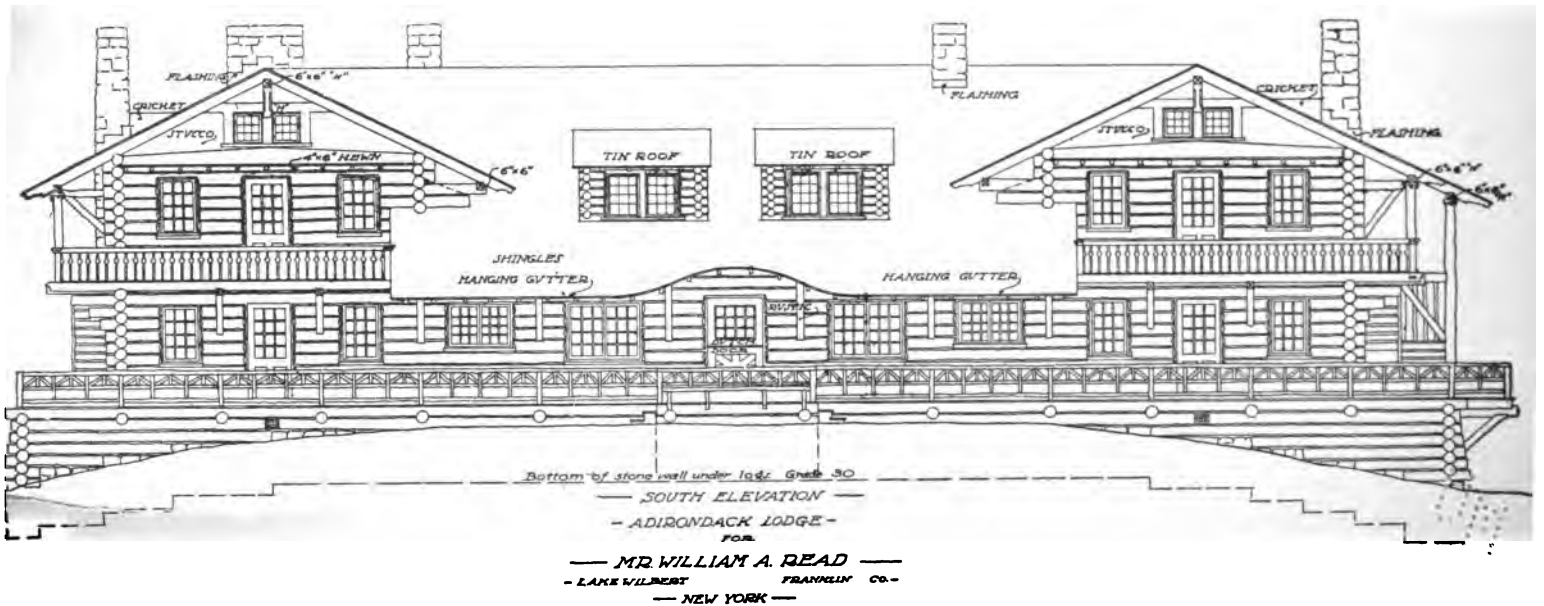
.....

[SEALS OF WAX OR WAFER.]

NOTE.—It will be observed that on each page, both of form of contract and of bond, each type line is numbered, 1, 2, 3, etc. This is customary in all such government documents, and is for the purpose of locating references, interlineations, etc.

At first glance, this contract appears to be one-sided in that it confers on one side certain seemingly arbitrary power which, if used in the extreme, would be disastrous to any Contractor; but, as a matter of fact, the Department uses its extreme rights with the utmost caution, and generally goes more than "half-way" in disputed settlements.

Where disaster occurs—such, for instance, as in a cyclonic wind, wrecking work in place, as happened at the Pan-American Exposition; or in damage by fire, as in the Baltimore conflagration—the Department promptly recommends that Congress make a reimbursing appropriation to be used in replacing work damaged; and that body always responds, recognizing a moral if not a legal obligation.



FRONT ELEVATION OF ADIRONDACK LODGE FOR WILLIAM A. READ, ESQ.
Davis, McGrath & Shepard, Architects, New York.

MECHANICAL DRAWING

PART I

The subject of mechanical drawing is of great interest and importance to all mechanics and engineers. Drawing is a method of showing graphically the minute details of machinery; it is the language by which the designer speaks to the workman; it is the most graphical way of placing ideas and calculation on record. A brief inspection of an accurate, well-executed working drawing gives a better idea of a machine than a lengthy written or verbal description. The better and more clearly a drawing is made, the more intelligently the workman can comprehend the ideas of the designer. Thorough training in this important subject is necessary to the success of everyone engaged in mechanical work.

The draftsman is dependent for his success, to a certain extent, upon the quality of the instruments and materials which he uses. As a beginner, he will find a cheap grade of instrument sufficient for his needs; but after he has become expert, it will be necessary for him to procure those of better construction and finish to enable him to do accurate work. It is a better plan to purchase the well-made instruments, if possible, at the start.

INSTRUMENTS AND MATERIALS

Drawing Paper. In selecting drawing paper, the first thing to be considered is the kind of paper most suitable for the proposed work. For shop drawings, a manila paper is frequently used on account of its toughness and strength, for these drawings are likely to be subjected to considerable hard usage. If a finished drawing is to be made, the best white drawing paper should be obtained, so that the drawing will not fade or become discolored with age. A good drawing paper should be strong; should have uniform thickness and surface; should stretch evenly and lie smoothly when stretched

or when ink or colors are used; should neither repel nor absorb liquids; and should allow considerable erasing without spoiling the surface. It is, of course, impossible to find all of these qualities in any one paper, as great strength cannot be combined with fine surface. However, a kind should be chosen which combines the greatest number of these qualities for the given work. Of the higher grades of papers, Whatman's are considered by far the best. This paper, either side of which may be used, is made in three grades: the *hot pressed*, which has a smooth surface and is especially adapted for pencil and very fine line drawing; the *cold pressed*, which is rougher than the hot pressed, has a finely grained surface, and is more suitable for water color drawing; and the *rough*, which is used for tinting. For general work, the cold pressed is the best as erasures do not show as plainly on it, but it does not take ink as well as the hot pressed.

Whatman's paper comes in sheets of standard sizes as follows:

Cap	13×17 inches	Imperial	22×30 inches
Demy	15×20 "	Atlas	26×34 "
Medium	17×11 "	Double Elephant . .	27×40 "
Royal	19×24 "	Antiquarian . . .	31×53 "
Super-Royal . . .	19×27 "		

The usual method of fastening paper to a drawing board is by means of thumb tacks or small one-ounce copper or iron tacks. First fasten the upper left-hand corner and then the lower right, pulling the paper taut. The other two corners are then fastened, and a sufficient number of tacks placed along the edges to make the paper lie smoothly. For very fine work, however, it is better to stretch the paper and glue it to the board. Turn up the edges of the paper all the way round—the margin being at least one inch—then moisten the surface of the paper by means of a sponge or soft cloth, and spread paste or glue on the turned-up edges. After removing all the surplus water on the paper, press the edges down on the board, commencing at one corner and stretching the paper *slightly*—if stretched too much it is liable to split in drying. Place the drawing board in a horizontal position until the paper is dry, when it will be found to be as smooth and tight as a drum head.

Drawing Board. The drawing board, Fig. 1, is usually made of well-seasoned and straight-grained soft pine, the grain running lengthwise of the board. Each end of the board is protected by a

side strip—1¾ to 2 inches in width—whose edge is made perfectly straight for accuracy in using the T-square. Frequently the end

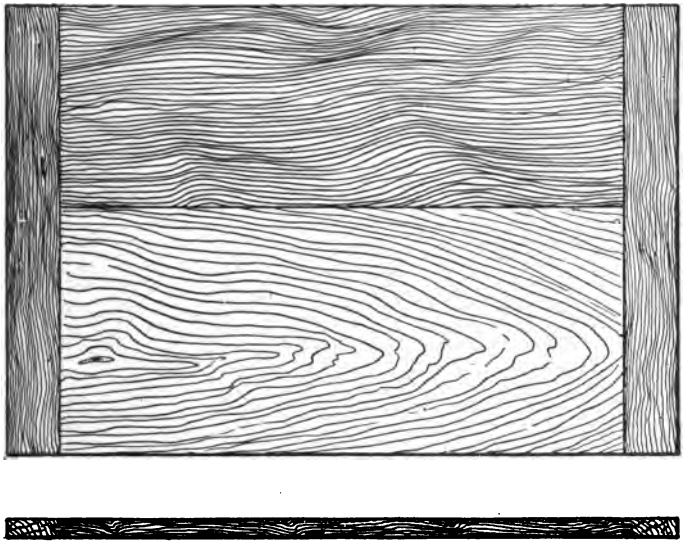


Fig. 1. Drawing Board

pieces are fastened by a glued matched joint, nails or screws. Tw. cleats on the bottom, extending the whole width of the board, will reduce the tendency to warp. Drawing boards are made in sizes to accommodate the sizes of paper in general use.

Thumb Tacks. Thumb tacks are used to fasten the paper to the drawing board. They are usually made of steel, pressed into shape—as in the cheaper grades—or with heads of German silver, the points being screwed and riveted to them. For most work, draftsmen use small one-ounce copper or iron tacks, as they are cheap and can be forced flush with the drawing-paper, thus offering no obstruction to the T-square.

Pencils. Lead pencils are graded according to their hardness, the degree of which is indicated by the letter H—as HH, 4H, 6H, etc. For general use a lead pencil of 5H or 6H should be used, although a softer 4H pencil is better for making letters, figures, and points. The hard lead pencil should be sharpened as shown in Fig. 2 so that in penciling a drawing the lines may be made very fine and light. The wood is cut away so that about ¼ or ½ inch of lead

projects. The lead can then be sharpened to a chisel edge by rubbing it against a bit of sand paper or a fine file, and the corners slightly rounded. In drawing the lines the draftsman should place the chisel edge against the T-square or triangle, thus enabling him to draw a fine line exactly through a given point. If the drawing is not to be inked, but is made for tracing or for rough usage in the shop, a softer pencil, 3H or 4H, may be used, so as to make the lines somewhat thicker and heavier. The lead for compasses may also be sharpened to a point although some draftsmen prefer to use a chisel edge for the compasses as well as the pencil.

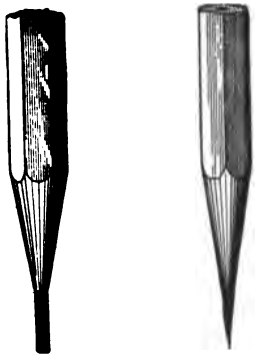


Fig. 2. Pencil Sharpened to a Chisel Point

In using a very hard lead pencil a light pressure should be used as otherwise the chisel edge will make a deep impression in the paper which cannot be erased.

Erasers. What little erasing is necessary in making drawings, should be done with a soft rubber. To avoid erasing the surrounding work some draftsmen use a card in which a slit is cut about 3 inches

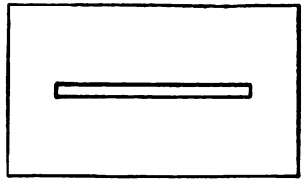


Fig. 3. Erasing Shield

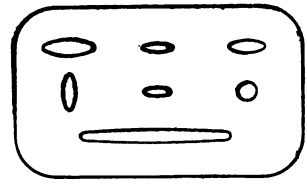


Fig. 4. Metal Erasing Shield

long and $\frac{1}{8}$ to $\frac{1}{4}$ inch wide, Fig. 3. An erasing shield of thin metal, Fig. 4, is also very convenient, especially in erasing letters. For cleaning drawings when they are completed, a sponge rubber or a preparation called "art gum" may be used, but in either case care should be taken not to make the lines dull by too hard rubbing.

T-Square. The T-square, which gets its name from its general shape, consists of a thin straight-edge, the *blade*, with a short piece, the *head*, fastened at right angles to it, Fig. 5. T-squares are usually made of wood, the pear and maple woods being used in the cheaper grades, and the harder woods, like mahogany, with protecting edges

of ebony or celluloid, Fig. 6, in the more expensive instruments. The head is designed to fit against the edge of the drawing board, allowing the blade to extend across the surface of the board. It is

Fig. 5. Common T-Square

desirable to have the blade of the T-square make a right angle with the head, but this is not absolutely necessary, if the head is always placed against the left-hand edge of the board, for the lines drawn

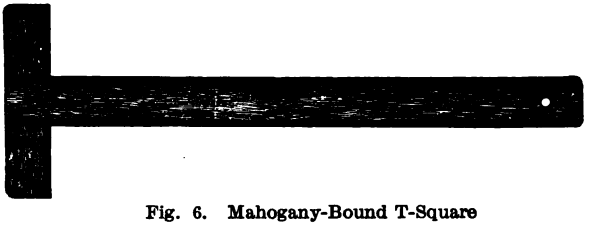


Fig. 6. Mahogany-Bound T-Square

with the T-square will then be referred to one edge of the board only, and if this edge is straight, the lines will be parallel to each other.

T-squares are sometimes provided with swiveled heads as it is frequently very convenient to draw lines parallel to each other which are not at right angles to the left-hand edge of the board. To use the T-square in drawing parallel horizontal lines,* place the head of the T-square in contact with the left-hand edge of the board, Fig. 7, and draw the pencil along the *upper edge* of the blade at each new position of the T-square. Only the upper edge should be used as the

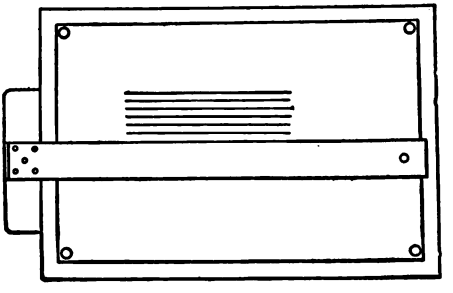


Fig. 7. Drawing Parallel Lines

* See page 23.

two edges may not be exactly parallel and straight. In trimming drawings or cutting the paper from the board, always use the *lower edge* of the T-square so that the upper edge may not be made untrue.

For accurate work it is absolutely necessary that the upper edge of the T-square be exactly straight. To test the straightness of the edge two T-squares may be placed together as shown in Fig. 8. However, a lack of contact such as shown in the figure does not prove which edge is crooked, and for this determination a third blade must be used and tried with the two given T-squares successively.

Fig. 8. Testing the Edge of T-Square

Triangles. Triangles are made of various substances such as wood, rubber, celluloid, and steel. Wooden triangles are cheap but are likely to warp out of shape; rubber triangles are frequently used, and are, in general, satisfactory; celluloid triangles are extensively used on account of their transparency, which enables the draftsmen to see the work already done even when covered with the triangle.

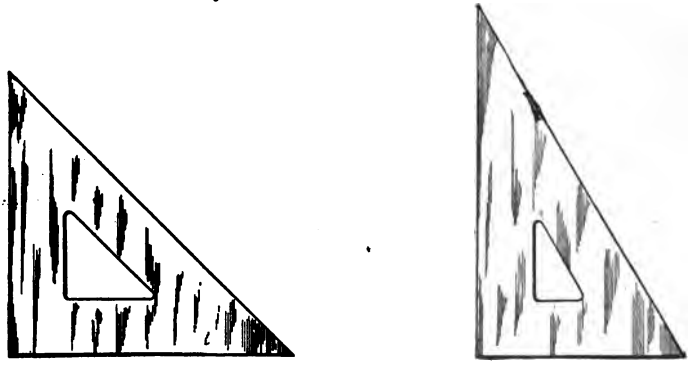


Fig. 9. 45° and 30° – 60° Triangles

In using a rubber or celluloid triangle take care that it lies perfectly flat and is hung up when not in use; when allowed to lie on the drawing board with a pencil or an eraser under one corner it will become warped in a short time, especially if the room is hot or the sun happens to strike the triangle.

Triangles from 6 to 8 inches on a side will be found convenient for most work, although there are many cases where a small triangle

measuring about 4 inches on a side will be found useful. Every draftsman should have at least two triangles, one having two angles of 45 degrees and one right angle; and the other having angles of 30, 60, and 90 degrees, respectively, Fig. 9.

The value of the triangle depends upon the accuracy of the angles and the straightness of the edges. To test the accuracy of

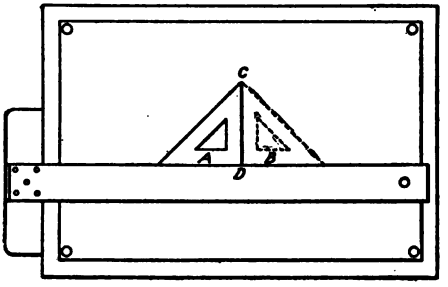


Fig. 10. Testing a Right Angle (45° Triangle)

the right angle of a triangle, place the triangle with the lower edge resting on the T-square in position *A*, Fig. 10. Now draw the line *C D*, which, if the triangle be true, will be perpendicular to the edge of the T-square. Transfer the triangle to position *B*, and if the right angle of the triangle is exactly 90 degrees the left-hand edge of the triangle will exactly coincide with the line *C D*.

To test the accuracy of the 45-degree angles place the triangle with the lower edge resting on the working edge of the T-square,

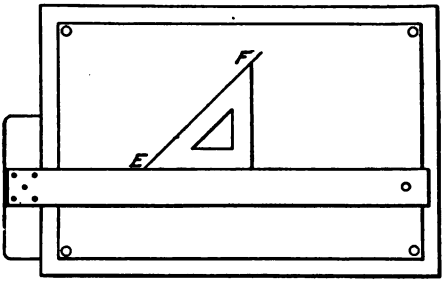


Fig. 11. Testing 45° Angle (45° Triangle)

and draw the line *E F*, Fig. 11. Now without moving the T-square place the triangle so that the other 45-degree angle is in the position occupied by the first. If the two 45-degree angles coincide they are accurate.

Triangles are used in drawing lines at right angles to the T-square, Fig. 12, and at an angle with the horizontal, Fig. 13. If it is desired to draw a line through the point *P*, Fig. 14, parallel to a given

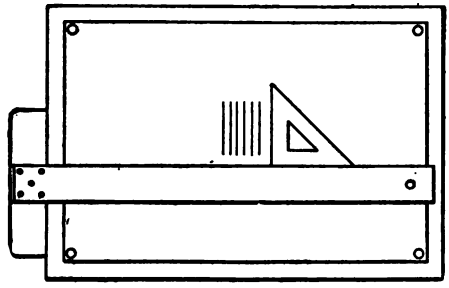


Fig. 12. Drawing Vertical Parallel Lines

line *E F*, two triangles should be used. First, place triangle *A* with one edge coinciding with the given line. Now take triangle *B* and place one of its edges in contact with the bottom edge of triangle *A*. Holding triangle *B* firmly with the left hand, slide triangle *A* to the right or to the left until its edge reaches the point *P*. The line *M N* may then be drawn passing through the point *P*. In place of the triangle *B* any straight-edge such as a T-square may be used.

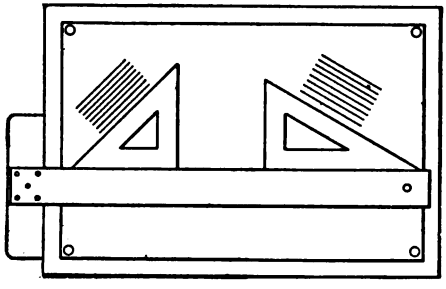


Fig. 13. Drawing Parallel Lines at an Angle with the Horizontal

A line may be drawn through a point, perpendicular to a given line by means of triangles as follows: Let *E F*, Fig. 15, be the given line, and let the point be *D*. Place the longest side of triangle *A* so that it coincides with the line *E F*. Place the other triangle (or any straight-edge) in the position of the triangle *B;* then holding *B* with the left hand, place the triangle *A* in the position *C*, so that the longest side passes through the point *D*. A line may then be drawn through the point *D* perpendicular to *E F*.

In previous figures it has been shown how lines may be drawn making angles of 30, 45, 60, and 90 degrees with the horizontal.

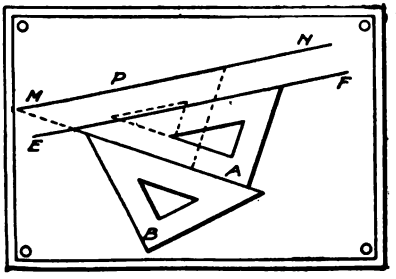


Fig. 14. Drawing a Line Parallel to a Given Line

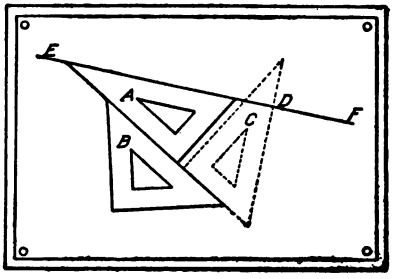


Fig. 15. Drawing a Line Perpendicular to a Given Line

It is possible to draw lines forming angles of 15 and 75 degrees by placing the triangles as shown in Fig. 16.

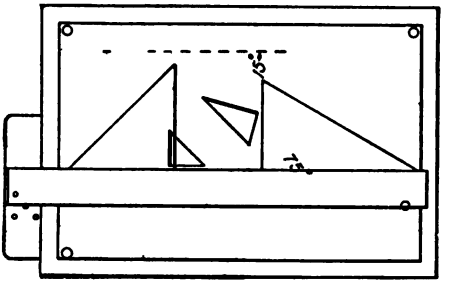


Fig. 16. Drawing Angle of 15° and 75°

By the use of the triangles and T-square almost any line may be drawn. Suppose it is desired to draw a rectangle having one side

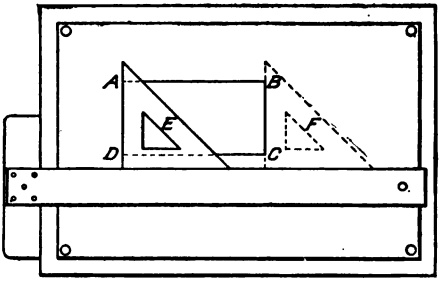


Fig. 17. Drawing a Rectangle with T-Square and Triangle

horizontal. First draw by means of the T-square the sides $A\,B$ and $D\,C$ horizontal and parallel, Fig. 17. Now place one of the

triangles on the T-square and in positions *E* and *F* draw the vertical lines *D A* and *B C*.

If the rectangle is to be drawn in some other position on the board, as shown in Fig. 18, place the 45-degree triangle *F* so that the longest edge is in the required direction of the side *D C*. Now, hold the triangle *F* in position and place another triangle in position *H*. By holding *H* in position and sliding triangle *F*, the sides *A B* and *D C* may be drawn. To draw the sides *A D* and *B C* change triangle *F* to position *E* and repeat the process.

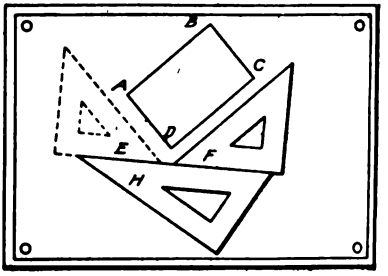


Fig. 18. Rectangle Drawn with Triangles

Compasses. Compasses are used for drawing circles and arcs of circles. The cheaper class of instruments are made of brass, but they are unsatisfactory on account of the odor and the tendency to tarnish. The best material is German silver, as it does not soil the hands, has no odor, and is easy to keep clean. Aluminum instruments possess the advantage of lightness, but on account of the softness of the metal they do not wear well.

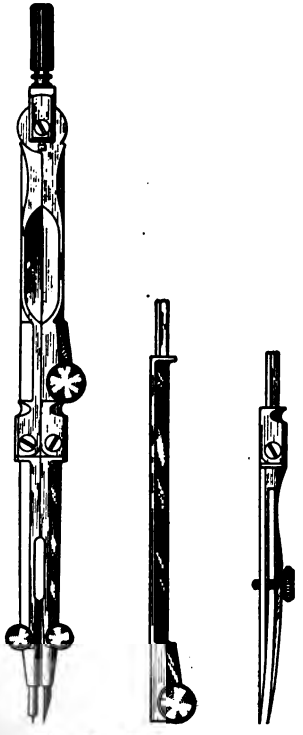


Fig. 19. Compasses and Attachments

The compasses are made in the form shown in Fig. 19 and are provided with pencil and pen points. Fig. 20 shows the compass in position for drawing circles. One leg has a socket into which the shank of the pencil or pen mounting may be inserted. The other leg is fitted with a needle point which is placed at the center of the circle. In most instruments the needle point projects through a piece of round steel wire with a square shoulder at one or both ends. In some instruments the joints are held in position by lock nuts,

made of thin disks of steel, with notches for using a wrench or forked key. Fig. 21 shows the detail of the joint of a high grade instrument. Both legs are alike at the joint, and two pivoted screws are inserted in the yoke. This permits ample movement of the legs, yet gives the proper stiffness. The flat surface of one leg is faced with steel, the other with German silver, so that the rubbing parts may be of different metals. Small set screws are used to prevent the pivoted screws from turning in the yoke. The contact surfaces of this joint are made circular to exclude dirt and to prevent rusting of the steel face.

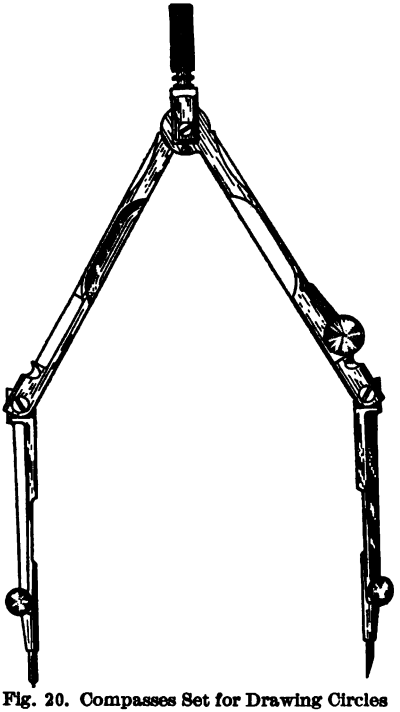


Fig. 20. Compasses Set for Drawing Circles

The details of the socket are shown in Fig. 22, Fig. 23, and Fig. 24; in some instruments the shank and socket are pentagonal, Fig. 22, the shank entering the socket loosely, and being held in place by means of the screw. Unless used very carefully this arrangement is not durable because the sharp corners soon wear, and the pressure on the set screw is not sufficient to hold the shank firmly in place.

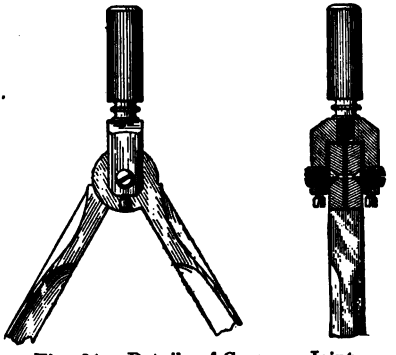


Fig. 21. Details of Compass Joint

In Fig. 23 is shown a round shank, the shank having a flat top, with a set screw to hold the shank in position. A still better form of socket is shown in Fig. 24, the hole being circular and tapered. The shank fits accurately into the split socket and is clamped by a screw on the side; it is held in perfect alignment by a small steel key.

Both legs of the compass are jointed in order that the lower part

of the legs may be perpendicular to the paper while drawing circles. In this way the needle point makes but a small hole in the paper, and both nibs of the pen will press equally on the paper. In penciling circles it is not as necessary that the pencil should be kept vertical;

Fig. 22. Pentagonal Shank and Socket

Fig. 23. Circular Shank and Socket

it is a good plan, however, to learn to use them in this way both in penciling and inking. The compasses should be held loosely between the thumb and forefinger. If the needle point is sharp, as it should be, only a slight pressure will be required to keep it in place. While drawing the circle, incline the compasses slightly in the direction of revolution and press lightly on the pencil or pen.

Fig. 24. Circular Socket with Set Screw

Fig. 25. Dividers

In removing the pencil or pen attachment from the compass it should be pulled out straight in order to avoid enlarging the socket, and thus rendering the instrument inaccurate. For drawing large circles use the lengthening bar, Fig. 19, steadying the needle point with one hand and describing the circle with the other.

Dividers. Dividers, which are similar to compasses, are used to lay off distances on the drawing, either from a scale or from other parts of the drawing, Fig. 25. They are also used for dividing a line into equal parts. To do this turn the dividers in the opposite direction each time, *i. e.*, move the point alternately to the right and to the left. The points of the dividers should be very sharp so that the holes made in the paper will be small, thus assuring accurate spacing. Compasses may be used as dividers by substituting for the pencil or pen point an extra steel point, usually furnished with the instrument. In place of dividers many draftsmen use a *needle point*. The needle, with the eye-end broken off, is forced into a handle of soft pine, making a convenient instrument for marking line intersections and distances.

Bow Pen and Bow Pencil. Ordinary large compasses are too heavy and the leverage of the long leg is too great to allow small circles to be drawn accurately. For this reason the bow compasses, Figs. 26 and 27, should be used on all arcs and circles having a radius of less than $\frac{3}{4}$ inch, such as those which represent boiler tubes and bolt

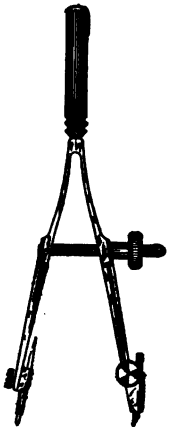


Fig. 26. Bow Pencil

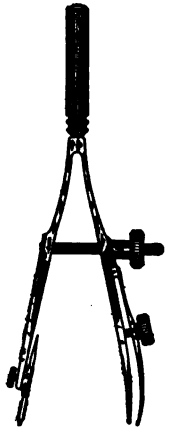


Fig. 27. Bow Pen

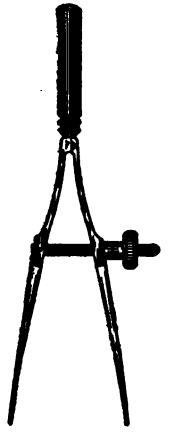


Fig. 28. Bow Divider

holes. When small circles are drawn, the needle point must be adjusted to the same length as the pen or pencil point. If a considerable change in radius is made, press the points together before turning the nut so as to prevent wear in the screw threads. The bow dividers, Fig. 28, replace the ordinary dividers in small work and have the advantage of a fixed adjustment.

Drawing Pen.* For drawing straight lines and curves that are not arcs of circles, the line pen—sometimes called the *ruling pen*—is

Fig. 29. Drawing Pen

used, Fig. 29. The distance between the pen points, which regulates the width of line to be drawn, is adjusted by the thumb screw, and the blades are given a slight curvature so that there will be a cavity for ink when the points are close together.

*See page 22.

The pen should not be dipped in the ink but should be filled by means of a common steel pen or quill, to a height of about $\frac{1}{4}$ or $\frac{3}{8}$ inch; if too much ink is placed in the pen it is likely to drop out and spoil the drawing. Upon finishing the work wipe the pen with chamois or a soft cloth, because most liquid inks corrode the steel.

In using the pen, care should be taken that both blades bear equally on the paper, in order that the line may be smooth. The pen is usually inclined slightly in the direction in which the line is drawn and should touch the triangle or T-square lightly so as not to press the blades together and thereby change the width of the line; the pen must not be tipped outward, however, as the danger of blotting is greatly increased when the line is drawn so close to the guide.

Sharpening the Drawing Pen. When it is impossible to make a smooth line with the drawing pen, it should be sharpened. Screw the blades together and grind them to a parabolic shape by drawing the pen back and forth over a small, flat, close-grained oilstone. This process, of course, makes the blades dull but insures their being of the same length. Now separate the points slightly and rub one of them on the oilstone, keeping the pen at an angle of from 10° to 15° with the face of the stone, and giving it a slight twisting movement. This part of the operation requires great care as the shape of the ends must not be altered. After one point has become fairly sharp, grind the other in a similar manner, grinding always on the *outside* of the blades and removing the burr from the inside with leather or pine wood. Test the pen by filling with ink and drawing several lines. Unless the lines are smooth, the grinding must be continued.

Ink. India ink is always used for drawing as it makes a permanent black line; it is obtainable in solid stick or liquid form. The liquid form is much more convenient but contains acid which corrodes steel and makes it necessary to keep the pen perfectly clean.

To prepare the ink in stick form for use, put a little water in a saucer and place one end of the stick in it; then by a twisting motion grind enough ink to make the water black and slightly thickened. Now draw a heavy line on a sheet of paper and if after drying the line has a grayish appearance, more grinding is necessary. Wipe the stick dry after using to prevent crumbling. It is well to grind the ink in small quantities as it does not dissolve readily a second time, however, if covered it will keep for two or three days.

Scales. The scales used for obtaining measurements on drawings are made in several forms, the most convenient being the *flat*, with beveled edges, and the *triangular*. The scale is usually graduated for a distance of 12 inches. The triangular scale, Fig. 30, has six

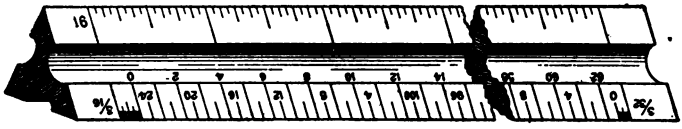


Fig. 30. Triangular Scale

surfaces for different graduations, and the scales are arranged so that the drawings may be made in any proportion to the actual size. For mechanical work, the common divisions are multiples of two; thus drawings are made full size, $\frac{1}{2}$ size, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, etc. If a drawing is $\frac{1}{4}$ size, 3 inches equals 1 foot, hence 3 inches is divided into 12 equal parts and each division represents one inch. If the smallest division on a scale represents $\frac{1}{16}$ inch, the scale is said to read to $\frac{1}{16}$ inch.

Scales are often divided into $\frac{1}{10}$, $\frac{1}{20}$, $\frac{1}{30}$, $\frac{1}{40}$, etc., for architects and civil engineers, and for measuring indicator cards.

The scale should never be used as a substitute for the triangle or T-square in drawing lines.

Protractor. The protractor, an instrument used for laying off and measuring angles, is made of steel, brass, horn, or paper. When

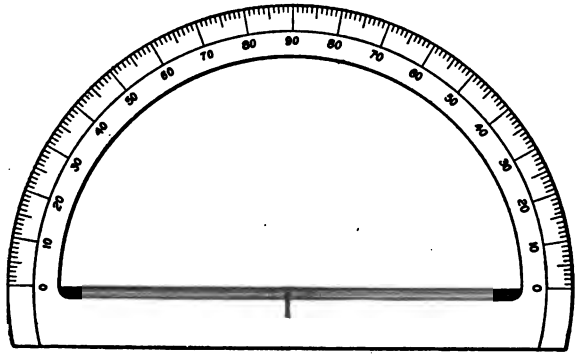


Fig. 31. Protractor

made of metal the central portion is cut out, Fig. 31, so that the draftsman may see the drawing. The outer edge is divided into degrees

and tenths of degrees. To lay off the required angle—use a very sharp, hard pencil in order that the measurements may be accurate—place the protractor so that the two zero marks are on the given line, produced, if necessary, and the center of the circle is at the point through which the desired line is to be drawn.

Irregular Curve. One of the conveniences of a draftsman's outfit is the *French* or *irregular curve*, which is used for drawing curves other than arcs of circles, with either pencil or line pen. This instrument, which is made of wood, hard rubber, or celluloid—celluloid being the best—is made in various shapes, one of the most common being shown in Fig. 32. Curves drawn with an irregular curve are called *free hand curves*.

To draw a curve through a series of located points find that position of the irregular curve that passes through three points,

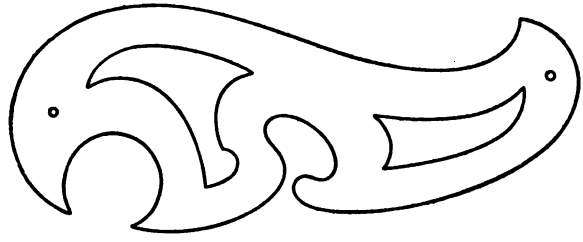


Fig. 32. Typical Irregular Curve

say, and draw the line through them, Fig. 33. Now shift the curve so as to include a part of the curve already drawn and two or three more points. Draw the curve through these points, continuing this process until the curve is completed. If, at each new setting, the line is not carried quite as far as the coincidence of the irregular curve would permit, a smoother curve will result. It frequently facilitates the work and improves its appearance to draw a pencil curve free hand through the points and then use the irregular curve, taking care that it always fits at least *three* points. In inking the curve, the blades of the pen must be kept tangent to the curve. For certain kinds of work, irregular curves of plastic metal are sometimes used to fit exceptionally erratic curves.

Beam Compasses. The ordinary compasses are suitable for drawing circles up to 8 or 10 inches diameter. For larger circles beam compasses are provided. The two parts called *channels*

which carry the pen or pencil and the needle point are clamped to a wooden beam at a distance equal to the radius of the circle. The

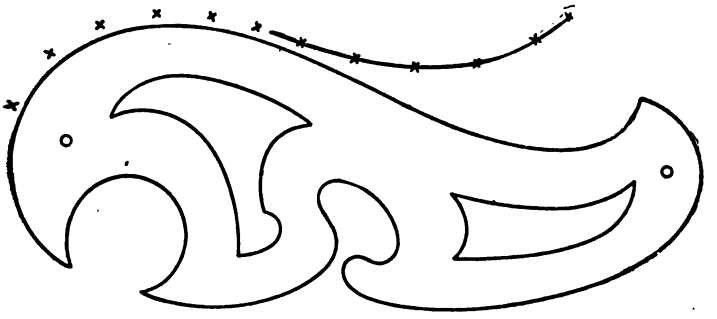


Fig. 33. Method of Using Irregular Curve

thumb nut underneath one of the channel pieces makes accurate adjustment possible.

LETTERING

No mechanical drawing is finished unless all headings, titles, and dimensions are lettered in plain, neat type. Many drawings are accurate, well-planned, and finely executed but do not present a good appearance because the draftsman did not think it worth while to letter carefully. Lettering requires time and patience especially for the beginner; and many think it a good plan to practice lettering before commencing drawing. Poor writing need not necessarily mean poor lettering, for good writers do not always letter well.

In making large letters for titles and headings it is often necessary to use drawing instruments and mechanical aids, but small letters, such as those used for dimensions, names of materials, dates, etc., should be made free-hand.

Forming. The student is apt to think that lettering is a form of mechanical drawing, that the use of the straight-edge is the principal operation, and that letters, forms, and the spaces between are to be figured out by measurement. On the contrary, lettering is design, and the draftsman so distributes the letters in the spaces arranged for them as to make a combination that will be pleasing to the eye. The requirements for a good design are simplicity and uniformity. These are acquired by accuracy in detail and by good judgment and taste, as no practical rules can be followed which will

invariably produce the same result. Letter forms are, to a certain extent, standard. The lettering for a title is usually done very carefully and accurately, while practically all of the other lettering on a drawing is done rapidly and in a simple style. To develop a letter use the same method of procedure as in drawing a straight line between two points. First, draw the guide lines rather carefully and then block out the general form of the letter by a series of short strokes of the pencil. Continue this method, straightening the lines and rounding the curves of the latter until its form is satisfactory.

Spacing. The spacing of the letters is very important and is best obtained by the unaided eye just as are the proportions of the letters. Care must be taken to allow a clear distance between letters, the space varying according to the combination. For instance, such letters as *A*, *V*, and *W* spread more at one part than at another and therefore do not fill the space completely. Of course, when the distance between letters is large any such irregularities will not be noticeable. The best method for obtaining good space values is by sketching in the letters roughly and then bringing them to a good appearance by correction and adjustment The first results are, of course, unsatisfactory, but after the eye and hand have become trained, great improvement will be noticed. A simple aid to this development will be found in the use of a piece of cardboard with the widths of the enclosing rectangles or parallelograms of the different letters marked on its edge, by which the spacing made by the eye may be checked.

Inking. In practical work most of the lettering is penciled in and then finished in ink. As faults in letters which may not be noticed in the penciled work stand out clearly after inking, it is not advisable to ink in the penciled letter accurately, but rather to improve upon it.

For lettering free-hand, use a pen that will make the full weight of line desired without much pressure, holding it squarely on the paper and directly in front. A new pen, which is apt to give too fine a line, may be remedied by scratching a little on a rough surface. If a pen is kept clean and all hardened ink removed so that the nibs are not spread, the pen will last a long time. A coarser pen must be used on rough than on smooth paper.

To remove a faulty line or a blot, let the ink dry thoroughly,

then with a sand rubber, erase the spot carefully, rubbing around it, as well. Clean the sand out of the surface with a pencil eraser and finally polish down with a piece of ivory or smooth wood. Pencil in the parts erased as if doing the work for the first time and again ink in, using special care, as the ink is more likely to spread on an erased surface than anywhere else.

Style. There are many styles of letters used by draftsmen, but almost any neat letter free from ornamentation is acceptable in regular practice. For titles, large Roman capitals are preferred, although Gothic and black letters also look well and are much easier to make. The vertical and inclined or italicized Gothic capitals shown in Fig. 34 and Fig. 35, are neat, plain, and easily made. This

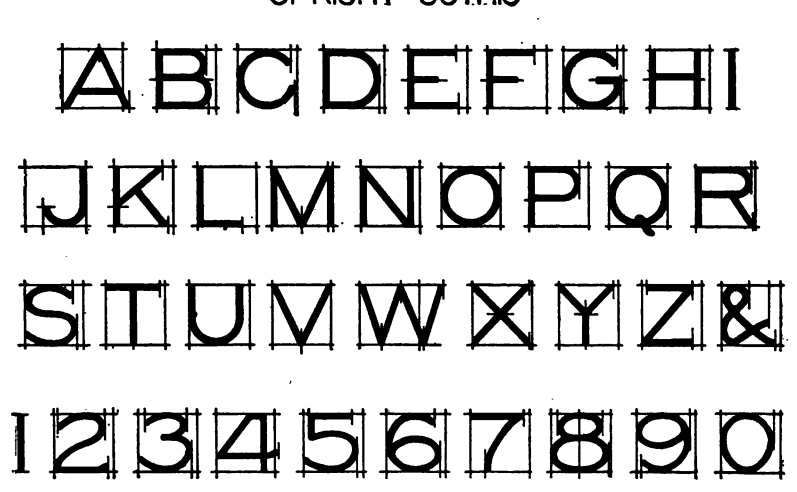


Fig. 34. Upright Gothic Capitals

latter style possesses the advantage over the vertical type in that a slight difference in inclination is not apparent.

The curves of the inclined Gothic letters such as those in *B*, *C*, *G*, *J*, etc., are somewhat difficult to make free-hand, especially if the letters are about one-half inch high. In the alphabet, Fig. 36, the letters are made almost wholly of straight lines, the corners only being curved.

The first few plates of this work will require no titles, the only lettering being the student's name, the date, and the plate number

which will be done in inclined Gothic capitals. Later the subject of lettering will again be taken up in connection with titles and headings for drawings which show the details of machines.

To make the inclined Gothic letters, first draw two parallel lines $\frac{5}{32}$ inch apart to mark the height for the letters of the date, name,

Fig. 35. Inclined Gothic Capitals

and plate number. This is the height to be used on all plates throughout this work, unless other directions are given. When two sizes of letters are used, the smaller should be about two-thirds as high as the larger. The inclination of the letters should be the same for all,

Fig. 36. Inclined Gothic Capitals— Straight Lines with Curved Corners

and as an aid to the beginner, light pencil lines may be drawn about $\frac{1}{4}$ inch apart, forming the proper angle with the parallel lines already drawn; this angle is usually about 70°, but if a 60° triangle is at hand, it may be used in connection with the T-square as shown in Fig. 38.

Capital letters such as *D*, *E*, *F*, *L*, *Z*, etc., should have their top and bottom lines coincide with the horizontal guide lines, as otherwise the work will look uneven. Letters, of which *C*, *G*, *O*, and *Q* are types, may be formed of curved or straight lines. If made of

curved lines, their height should be a little greater than the guide lines to prevent their appearing smaller than the other letters. In this work they may be made of straight lines with rounded corners as such letters are easily constructed and may be made of standard height.

To construct the letter *A*, use one of the 60° lines as a center line. Then from its intersection with the upper horizontal line drop a perpendicular to the lower guide line. Draw another line from the vertex meeting the lower guide line at the same distance on the other side of the center line. The cross line of the *A* should be a little below the center. The *V* is an inverted *A* without the cross line. For the letter *M*, the side lines should be parallel and about the same distance apart as the guide lines. The side lines of the *W* are *not* parallel but are farther apart at the top. The *J* is not quite as wide as such letters as *H*, *E*, *N*, *R*, etc. To make a *Y*, use the same spread as in making a *V* but let the diverging lines meet the center line a little below the middle.

The lower-case letters are shown in Fig. 37. In such letters

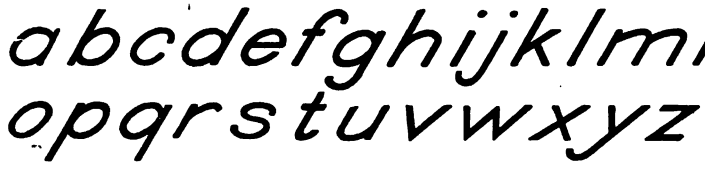


Fig. 37. Inclined Gothic Lower-Case Letters

as *m*, *n*, *r*, etc., make the corners slightly rounding. The letters *a*, *b*, *c*, *e*, *g*, *o*, *p*, *q*, should be full and rounding.

The style of the Arabic numerals is given in Fig. 36; Roman numerals are made of straight lines.

At first the copy should be followed closely and the letters drawn in pencil; the inclined guide lines may be used until the proper inclination becomes firmly fixed in mind when they should be abandoned. The horizontal lines, however, are used at all times by most draftsmen. After considerable practice has been had the letters may be constructed in ink without first using the pencil. When proficiency has been attained in the simple inclined Gothic capitals, the vertical, block and Roman alphabets should be studied.

HOW TO HOLD DRAWING INSTRUMENTS

Position of Hand and Instruments. To the student who is just starting out with his drawing work, the position in which he holds his instruments and the free and easy posture of his hands are very important. Just as in playing the piano or in any other process where manual dexterity is required, this skill can only be attained by practice. The following studies should be used in connection with

Position 1. Right Line Pen against T-Square or Triangle

the instructions given in the forepart of this book and wherever references have been given to this section, it is expected that the student will study these plates so as to receive helpful suggestions in his work. In developing skill in Mechanical Drawing, practice is the only method of achieving results after the fundamental principles have been mastered. A very useful collection of "DON'TS" is given herewith and these will bear very close study.

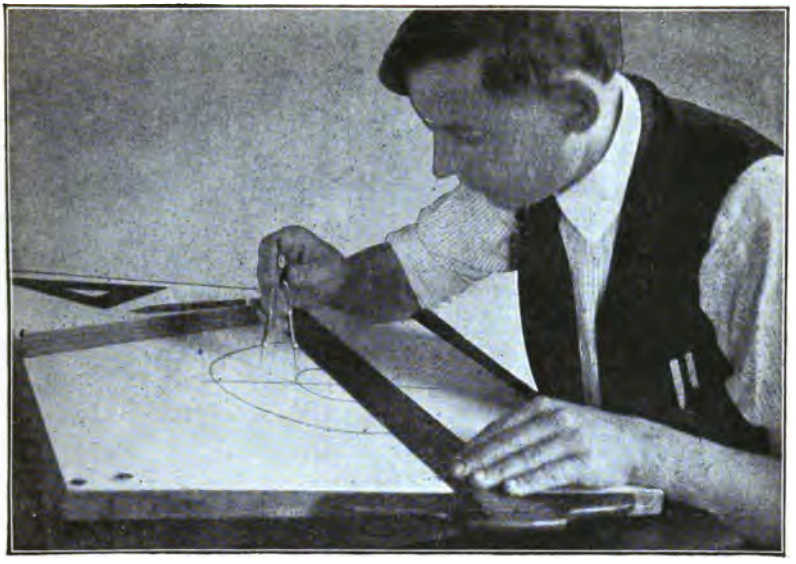
Position 2. Drawing Pencil Line with T-Square and Triangle

Position 3. Inking a Line with Pen and T-Square

Position 4. Drawing Small Circle with the Compass

Position 5. Drawing Large Circle with Compass with Bent Legs

Position 6. Drawing Very Large Circle with Spread Compass and Lengthening Bar



Position 7. Adjusting Dividers with One Hand. Note Second and Third Fingers between Legs

"DON'TS" IN DRAFTING WORK

Don't fold a drawing.
Don't stick the dividers into the drawing board.
Don't use the dividers as picks.
Don't use the scale to rule lines.
Don't fail to clean the table, board, and instruments when beginning work.
Don't draw on the lower edge of the T-square.
Don't cut the sheets of drawing paper with the upper edge of the T-square and a knife; use the lower edge.
Don't put the end of a pencil in the mouth.
Don't oil the compass joints.
Don't put away the instruments without cleaning, especially pens.
Don't use the cheapest materials.
Don't use the T-square as a hammer.
Don't screw up the nibs of the pen too tight.
Don't use a blotter on lines that have been inked.
Don't run the pen or pencil backward over a line.
Don't fill a pen over a drawing.

PRELIMINARY LINE PROBLEMS

To lay out the paper for the plates of this work, place a sheet *A B G F*, Fig. 38, on the drawing board 2 or 3 inches from the left-hand edge, called the *working edge.* If placed near the left-hand edge, the T-square and triangles can be used with greater firmness and the horizontal lines drawn with greater accuracy. In fastening the paper on the board, always true it up with the T-square according to the long edge of the sheet and use at least 4 thumb tacks —one at each corner. If the paper has a tendency to curl, 6 or 8

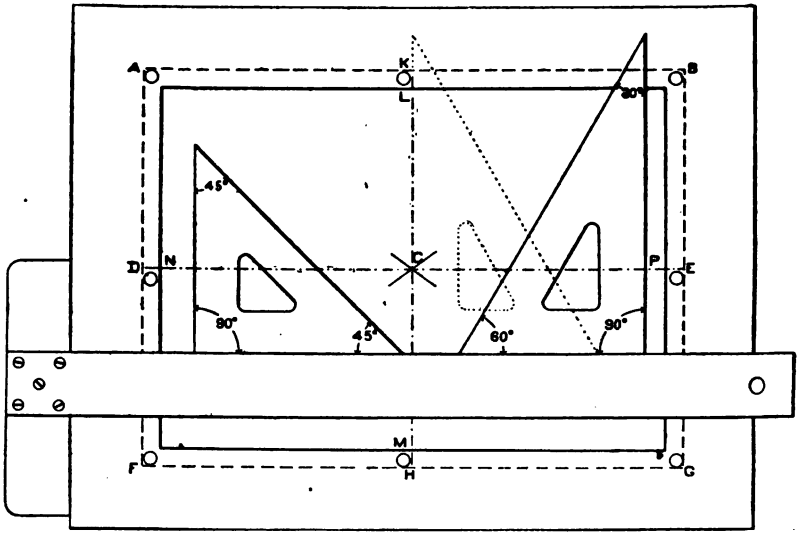


Fig. 38. Standard Lay-Out for Plates

tacks may be used placing them as shown in Fig. 38; many draftsmen prefer one-ounce tacks as they offer less obstruction to the T-square and triangles.

To find the center of the sheet place the T-square so that its upper edge coincides with the diagonal corners *A* and *G* and with the corners *F* and *B*, and draw short pencil lines intersecting at *C*. Now with the T-square draw through the point *C* the dot and dash line *D E*, and with the T-square and one of the triangles—shown dotted in Fig. 38—draw the dot and dash line *H C K*. It will probably be necessary to draw *CK* first and then by means of the T-square or triangle, produce (extend) *CK* to *H*. In this work always move

the pencil from left to right or from the bottom upward; except in certain cases.

After the center lines are drawn measure off 5 inches above and below the point C on the line $H\,C\,K$. These points L and M may be indicated by a light pencil mark or by a *slight* puncture by means of one of the points of the dividers. Now place the T-square against the left-hand edge of the board and draw horizontal pencil lines through L and M.

Measure off 7 inches to the left and right of C on the center line $D\,C\,E$ and draw pencil lines through these points N and P, perpendicular to DE. These lines form a rectangle 10 inches by 14 inches, in which all the exercises and figures are to be drawn. The lettering of the student's name and address, date, and plate number are to be placed *outside* of this rectangle in the $\frac{1}{2}$-inch margin. In all cases lay out the plates in this manner and keep the center lines $D\,E$ and $K\,H$ as a basis for the various figures. Ink in the border line with a heavy line when the drawing is finished.

Penciling. In laying out the first few plates of this course the work is to be done in pencil and then inked in; later the subject of tracing the pencil drawings on tracing cloth and the process of making blue prints from these tracings will be taken up. Every beginner should practice with his instruments until he understands them thoroughly and can use them with accuracy and skill. To aid the beginner in this work, the first three plates of this course are practice plates; they do not involve any problems and none of the work is difficult. The student is strongly advised to draw these plates two or three times before making the one to be sent to us for correction. Diligent practice is necessary at first; especially on *Plate I* as it involves an exercise in lettering.

Inking. To ink a drawing well requires great care and some experience. The student should not attempt to ink in his work until he can make a clear-cut, straight line with ease. It is well to practice inking in straight pencil lines, rectangles, and triangles in order to improve the work on lines, corners, and intersections. These latter should be very definite, each line stopping at exactly the right point.

Before starting to ink in, adjust the pen by means of the thumb screw until a good clear line of the desired width is obtained, making frequent test lines, on a piece of material similar to that which is to

be used. Keep the pressure of the pen on the paper uniformly light, remembering that different weights of lines are not obtained by pressure as with the ordinary writing pen but only by adjusting the nibs of the pen. If the lines are ragged the pen should be put in order, according to the instructions already given. Sometimes when the ink does not flow regularly, moisten the end of the finger and touch the point of the pen. Care should be taken not to put too much ink in the pen, but on the other hand there must be enough to draw the next line as it is difficult to continue a line after re-filling the pen. The only way to draw fine lines well is to frequently clean and re-fill the pen. If the amount of ink in the pen is small it is quite likely to thicken in the point and cause clogging. When this occurs, draw a small strip of paper between the nibs to clean out the clogged ink.

When drawing, the pen should be held with the thumb screw out and should be inclined slightly in the direction in which it is moved. Be careful, however, not to incline it too much, as the best of pens when incorrectly held will produce poor lines. It is therefore advisable at the start to acquire the correct method of holding the pen. Do not press the sides of the pen point too heavily against the ruling edge as this will vary the width of the line; after a little practice the pen can be lightly and firmly brought in contact with the paper and ruling edge at the same time. The pen should be drawn from left to right, the hand being steadied by sliding it on the end of the little finger.

Always try to get into the easiest position when inking a line, even if it becomes necessary to walk around the drawing. The average draftsman prefers the standing position while inking as he can usually obtain much better results. Keep the ruling edge between the line and the body so that the pen will be drawn against the ruling edge, for if this is not done, the pen is liable to be pulled off at an angle, making a crooked line. Be careful after inking a line to draw the ruling edge toward the body away from the line in order to avoid blotting. Where lines meet at a point, always ink towards the point, being sure to allow one line to dry before inking another. Always ink in the top and left-hand lines first, gradually working down to the right, thus saving time that otherwise would be lost in waiting for the lines to dry. When the pen is set at the proper width, draw all the lines of that width before making a change. Never push

the pen backward over a line. If a good line is not drawn the first time, it is better to go over it again in the same direction, taking great care not to widen the original line.

Ink dries very quickly and should not be left in the pen on account of its corrosive effects. The celluloid triangles should be washed frequently in water and all ink spots removed.

In using the compass, bend both legs so that each will be perpendicular to the paper or cloth when the arc or circle is drawn. When the pen attachment is used special care must be exercised on this point for in no other way can the nibs of the pen be made to bear evenly on the surface. In drawing arcs, hold the cylindrical handle at the top of the compass loosely between the thumb and the forefinger and let it roll between the two during rotation; allow the compass to lean slightly in the direction of rotation, pressing down the pen point slightly but not the needle point. Be sure to fix the needle point firmly in its proper place on the paper before touching the pen to the paper, as otherwise a slip is likely to occur. In setting the needle down on any particular center, guide it with a finger of the left hand. Avoid making a noticeable hole in the paper.

Ink in the circumference of a circle with one continuous motion, giving an even pressure to the pen throughout the operation and stopping it sharply at the end of one revolution. Since straight lines can be more easily drawn tangent to curves than the reverse, it is always advisable to ink in all arcs or circles first. When a number of circles are to be drawn from one center, the smaller should be inked first while the center is in the best possible condition.

PLATE I

Penciling. To draw *Plate I*,* take a sheet of drawing paper at least 11 inches by 15 inches and fasten it to the drawing board as already explained. Find the center of the sheet and draw fine pencil lines to represent the lines *DE* and *HK* of Fig. 38. Also draw the border lines *L*, *M*, *N*, and *P*.

Now measure $\frac{3}{8}$ inch above and below the horizontal center line and, with the T-square, draw lines through these points. These lines will form the lower lines *DC* of Fig. 1 and Fig. 2 and the top lines *AB* of Fig. 3 and Fig. 4. Measure $\frac{3}{8}$ inch to the right and left

*Note Instructions, pages 22 to 25, inclusive.

TRIM THE SHEET TO THE SIZE SHOWN BY DASH LINES

PLATE I

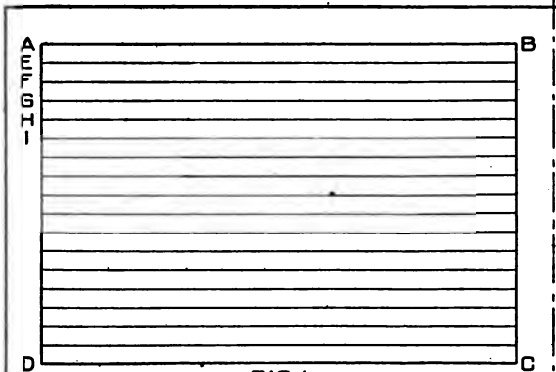


FIG. 1

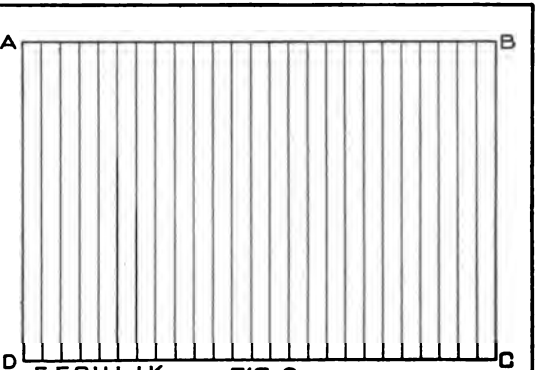


FIG. 2

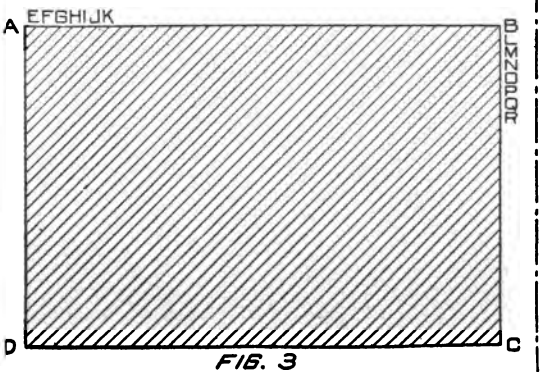


FIG. 3

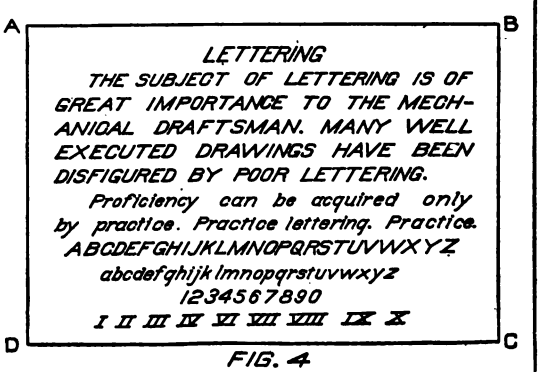

A
B
LETTERING
THE SUBJECT OF LETTERING IS OF GREAT IMPORTANCE TO THE MECHANICAL DRAFTSMAN. MANY WELL EXECUTED DRAWINGS HAVE BEEN DISFIGURED BY POOR LETTERING.
Proficiency can be acquired only by practice. Practice lettering. Practice.
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijk lmnopqrstuvwxyz
1234567890
I II III IV VI VII VIII IX X
D
C

FIG. 4

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HERBERT CHANDLER, CHICAGO, ILL.

of the vertical center line; and through these points, draw lines parallel to the center line. These lines should be drawn by placing the triangle on the T-square as shown in Fig. 38. The lines thus drawn, form the sides *B C* of Fig. 1 and Fig. 3 and the sides *A D* of Fig. 2 and Fig.4. Next draw, with the T-square, the line *A B A B* 4⅝ inches above the horizontal center line, and the line *D C D C* 4⅝ inches below the horizontal center line. The rectangles of the four figures may now be completed by drawing vertical lines 6⅝ inches on each side of the vertical center line; these rectangles are each 6¼ inches long and 4¼ inches wide.

Fig. 1. *Exercise with Line Pen and T-square.* Divide the line *A D* into divisions each ¼ inch long, making a fine pencil point or *slight* puncture at each division such as *E, F, G, H, I,* etc. Now place the T-square with its head at the left-hand edge of the drawing board and through these points draw light pencil lines extending to the line *B C*. In drawing these lines the pencil point must pass *exactly* through the division marks so that the lines will be the same distance apart. Start each line in the line *A D* and do not fall short of the line *B C* or run over it. Accuracy and neatness in penciling insure an accurate drawing. Some beginners think that they can correct inaccuracies while inking; but experience soon teaches them that they cannot do so.

Fig. 2. *Exercise with Line Pen, T-square and Triangle.* Divide the lower line *D C* of the rectangle into divisions each ¼ inch long and mark the points *E, F, G, H, I, J, K,* etc., as in Fig. 1. Place the T-square about as shown in Fig. 38, and either triangle in position with its 90-degree angle at the left. Now draw fine pencil lines from the line *D C* to the line *A B* passing through the points *E, F, G, H, I, J, K,* etc., keeping the T-square rigid and sliding the triangle toward the right.

Fig. 3. *Exercise with Line Pen T-square and 45-degree Triangle.* Lay off the distances *A E, B L,* etc., each ¼ inch long on *A B* and *B C*, respectively. Place the T-square so that the upper edge will be below the line *D C*, and, with the 45-degree triangle, draw the diagonal lines through the points laid off. In drawing these lines move the pencil away from the body, *i. e.*, from *A D* to *A B* and from *D C* to *B C*.

Fig. 4. *Exercise in Free-Hand Lettering.* Draw the center line *E F*, Fig. 39, and light pencil lines *Y Z* and *T X*, ⅜ inch from the

border lines. With the T-square, draw the line G, $\frac{1}{4}$ inch from the top line and the line H, $\frac{5}{32}$ inch below G. The word "*LETTERING*" is to be placed between these two lines. Draw the line I, $\frac{3}{16}$ inch below H, and space the lines included between I and K, $\frac{5}{32}$ inch apart.

The next style of letters to be discussed is lower-case letters. Draw the line L $\frac{3}{16}$ inch below K and to limit the height of the small letters draw a light line $\frac{1}{8}$ inch above L.

Make the space between L and M, $\frac{5}{32}$ inch and draw M and N in the same manner as K and L. Now draw O, $\frac{3}{16}$ inch below N,

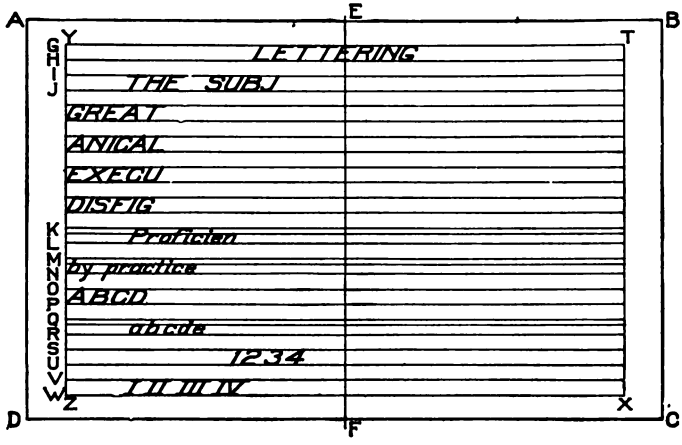


Fig. 39. Sample Lettering Plate—Fig. 4., Plate I

P, $\frac{5}{32}$ inch below O, and Q, $\frac{5}{32}$ inch below P. Space Q and R as K and L, and draw S, U, V, and W, $\frac{5}{32}$ inch apart.

The center line is a great aid in centering the word "*LETTERING*," the alphabets, numerals, etc. Indent the words "*THE*" and "*Proficiency*" about $\frac{3}{8}$ inch, as they are the first words of paragraphs. To draw the guide lines, mark off distances of $\frac{1}{4}$ inch on any line such as J and with the 60-degree triangle draw light pencil lines cutting the parallel lines. Sketch the letters in pencil making the width of the ordinary letters such as E, F, H, N, R, etc., about $\frac{3}{4}$ their height. Letters like A, M, and W, are wider. The space between the letters depends upon the draftsman's taste, but the beginner should remember that letters next to an A or an L should be placed nearer to them than to letters whose sides are parallel; for

instance there should be more space between an *N* and *E* than between an *E* and *H*. Similarly a greater space should be left on either side of an *I*. On account of the space above the lower line of the *L*, a letter following an *L* should be close to it. If a *T* follows a *T* or an *L* follows an *L* place them near together. In all lettering place the letters so that the general effect is pleasing. After the four figures are completed, pencil in the lettering for name, address, and date. With the T-square draw a pencil line $\frac{5}{32}$ inch above the top border line at the right-hand end, and about 3 inches long. At a distance of $\frac{5}{32}$ inch above this line draw another line of about the same length. These are the guide lines for the word *Plate I*. Pencil the letters free-hand using the 60-degree guide lines if desired.

Draw in a similar manner the guide lines of the date, name, and address in the lower margin, the date of completing the drawing placed under Fig. 3, and the name and address at the right, under Fig. 4. The street address is unnecessary. It is a good plan to draw lines $\frac{5}{32}$ inch apart on a separate sheet of paper and pencil the letters in order to know just how much space each word will require. The insertion of the words "Fig. 1," "Fig. 2," etc., is optional with the student, but it is advised that he do this extra lettering for the practice as well as for convenience in reference. First draw with the T-square two parallel lines $\frac{5}{32}$ inch apart under each exercise, the lower line being $\frac{1}{16}$ inch above the horizontal center line or above the lower border line.

Inking. After all of the penciling of *Plate I* has been completed the exercises should be inked. Before doing this, however, see that the pen is in proper condition, and after filling try it on a separate piece of paper in order that the proper width of line may be drawn. In the first work where no shading is done, use a firm, distinct line. The beginner should avoid the extremes; a very light line makes the drawing appear weak and indistinct, while a very heavy line detracts from its artistic appearance.

Ink in all the horizontal lines of Fig. 1 first, moving the T-square from *A* to *D*, and take great care to start and stop the lines exactly on the vertical boundary lines. It is necessary to use both triangle and T-square for inking *A D* and *B C*. In inking Fig. 2 and Fig. 3, follow the same directions as for penciling, inking in the vertical and oblique lines first and then the border lines. Ink the border lines

of Fig. 4 first and then the border lines of the plate, making the latter very heavy and the intersections accurate. The lettering in Fig. 4 should be done free-hand, using a steel pen not finer than a Gillott 404. Now ink in the four figure numbers, plate number, date, and name, also free-hand, and then erase the pencil lines. **In the finished drawing there should be no center lines, construction lines, or letters other than those in the name, date, etc.**

Cut the sheet 11″ × 15″, the dash line outside the border line of *Plate I* indicating the edge.

PLATE II

Penciling. The horizontal and vertical center lines and the border lines for *Plate II* are laid out in the same manner as were those of *Plate I*. To draw the squares for the six figures, proceed as follows:

Measure off two inches on either side of the vertical center line and draw light pencil lines through these points parallel to the vertical center line. These lines will form the sides *A D* and *B C* of Fig. 2 and Fig. 5. Parallel to these lines and at a distance of ½ inch draw similar lines to form the sides *B C* of Fig. 1 and Fig. 4 and *A D* of Fig. 3 and Fig. 6. The vertical sides *A D* of Fig. 1 and Fig. 4 and *B C* of Fig. 3 and Fig. 6 are formed by drawing lines perpendicular to the horizontal center line at a distance of 6½ inches from the center.

Complete the figures by laying off lines ½ inch and 4½ inches above and below the horizontal center line respectively, thus forming six 4-inch squares.

In drawing Fig. 1, divide *A D* and *A B* into 4 equal parts, then draw horizontal lines through *E*, *F*, and *G* and vertical lines through *L*, *M*, and *N*. Draw lines from *A* and *B* to the intersection *O* of lines *E* and *M*, and from *A* and *D* to the intersection *P* of lines *F* and *L*. Similarly draw *D J*, *J C*, *C I*, and *I B*. Also connect the points *O*, *P*, *J*, and *I*, thus forming a square. The four diamond-shaped areas are formed by drawing lines from the middle points of *A D*, *A B*, *B C*, and *D C* to the middle points of lines *A P*, *A O*, *O B*, *I B*, etc., as shown in Fig. 1.

Fig. 2 is an exercise of straight lines. Divide *A D* and *A B* into four equal parts and draw horizontal and vertical lines as in Fig. 1. Now divide these dimensions, *A L*, *M N*, etc., and *E F*,

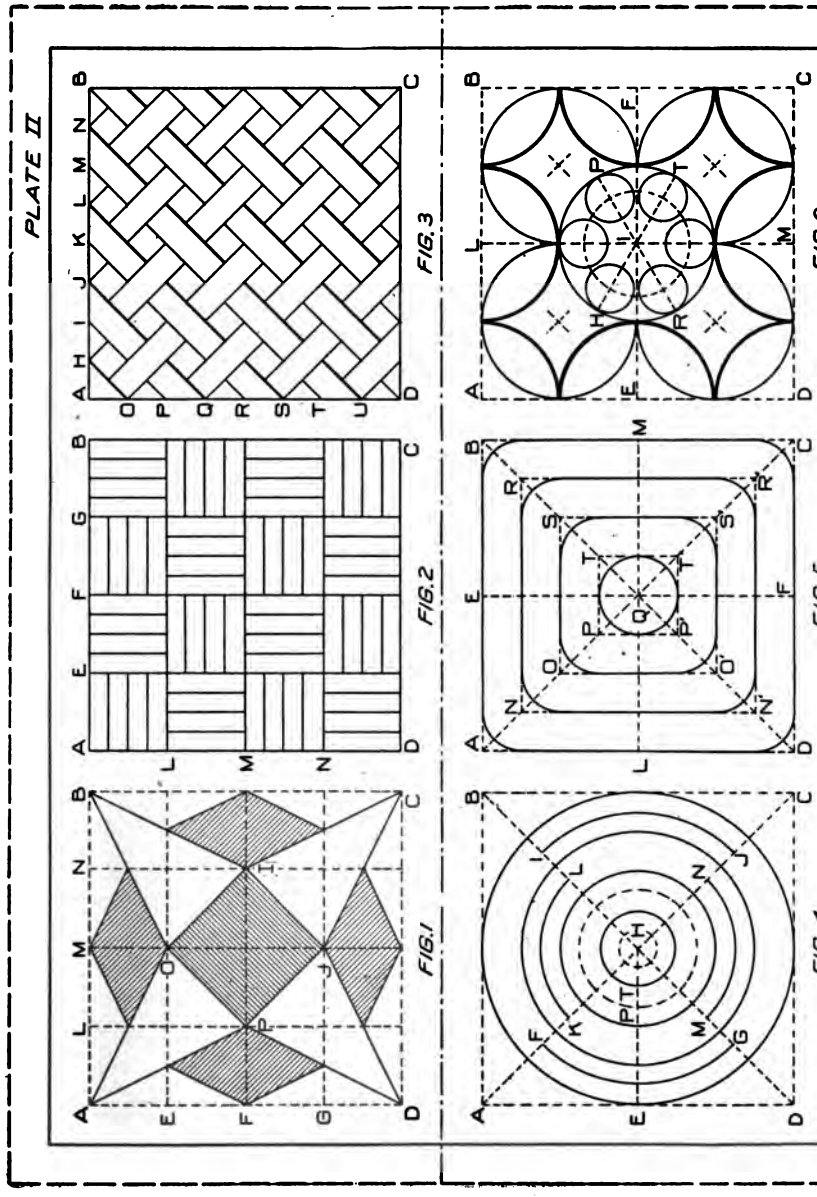


PLATE II
FIG. 1
FIG. 2
FIG. 3
FIG. 4
FIG. 5
FIG. 6

G B, etc., into four equal parts—each ¼ inch—and draw light pencil lines with the T-square and triangle as shown.

In Fig. 3, divide *A D* and *A B* into eight equal parts, and through the points *O*, *P*, *Q*, *H*, *I*, *J*, etc., draw horizontal and vertical lines. Now draw lines connecting *O* and *H*, *P* and *I*, *Q* and *J*, etc. As these lines form an angle of 45 degrees with the horizontal, a 45-degree triangle may be used. Similarly from each one of the given points on *A B* and *A D*, draw lines at an angle of 45 degrees to *B C* and *D C* respectively.

Fig. 4 is drawn with the compasses. Draw the diagonals *A C* and *D B*, and with the T-square draw the line *E H*. Now mark off on *E H* distances of ¼ inch, and with *H* as a center describe, by means of the compasses, circles having radii respectively 2 inches, 1½ inches, 1 inch, ¾ inch, ½ inch, and ¼ inch. Similarly with *H* as a center and a radius of 1¾ inches and 1¼ inches respectively draw the arcs *F G* and *I J* and *K L* and *M N*, being careful to end the arcs in the diagonals.

Fig. 5 is an exercise with the line pen and compasses. Draw the diagonals *A C* and *D B*, the horizontal line *L M* and the vertical line *E F* passing through the center *Q*. Mark off distances of ½ inch on *L M* and *E F* and complete the squares *N R R' N'*, etc. With the bow pencil adjusted so that the distance between the pencil point and the needle point is ½ inch, draw arcs having centers at the corners of the inner squares. The arc whose center is *N* will be tangent to the lines *A L* and *A E* and the arc whose center is *O* will be tangent to *N N'* and *N R*. Since the smallest square has 1 inch sides, the ½-inch arcs drawn with *Q* as a center will form a circle.

In Fig. 6, draw the center lines *E F* and *L M*, and find the centers of the four squares thus formed. Through the center *I* draw the construction lines *H I T* and *R I P* forming angles of 30 degrees with *EF*. Now adjust the compasses to draw circles having a radius of one inch, and with *I* as a center, draw the circle *H P T R*. With the same radius draw the arcs with centers at *A*, *B*, *C*, and *D*, and also draw the semicircles with centers at *L*, *F*, *M*, and *E*. Now draw the arcs as shown having centers at the centers of the four squares. To locate the centers of the six small circles within the circle *H P T R*, draw a circle with a radius of $\frac{11}{16}$ inch and having the center in *I*. The small circles each have a radius of $\frac{5}{16}$ inch.

Inking. In *Plate II* ink in only the lines shown *full* in the specimen plate. First ink the star and then the square and diamonds. As this is an exercise for practice, the cross-hatching should be done *without* measuring the distance between the lines and without the aid of any cross-hatching device. The lines should be about $\frac{1}{16}$ inch apart. After inking in the plate all construction lines should be erased.

In inking Fig. 2 first ink the principal horizontal and vertical lines and then very carefully ink in the short lines. Make these lines all of the same width.

Fig. 3 is drawn entirely with the 45-degree triangle. In inking the oblique lines make *P I*, *R K*, *T M*, etc., of the usual width, while the alternate lines *O H*, *Q J*, *S L*, etc., should be somewhat heavier. All of the lines which slope in the opposite direction are light. Now ink in the border lines and erase all other horizontal and vertical lines.

In inking Fig. 4 use only the compasses, adjusting the legs so that the pen will always be perpendicular to the paper. In inking the arcs, see that the pen stops *exactly* at the diagonals. The inner circle and the next but one should be dotted as shown in the specimen plate. After inking the circles and arcs erase the construction lines that are without the outer circles, leaving in *pencil* the diagonals inside the circles.

In Fig. 5 *draw all arcs first* and then the straight lines meeting these arcs, as it is much easier to make a straight line meet an arc or tangent to it, than the reverse. Leave all construction lines in pencil. This exercise is difficult, and as in all mechanical and machine drawing, arcs and tangents are frequently used, the beginner is advised to draw this exercise several times.

Fig. 6 is an exercise with compasses. If the laying out has been accurately done in pencil, the inked arcs will be tangent to each other and the finished exercise will have a good appearance. If, however, the distances were not accurately measured and the lines carefully drawn, the inked arcs will not be tangent. The arcs whose centers are *L*, *F*, *M*, and *E*, and *A*, *B*, *C*, and *D* should be heavier than the rest. The small circles may be drawn with the bow pen. After inking the arcs all construction lines should be erased.

Finally ink in the figure numbers, the border lines of the plate, name, address, and plate number as in *Plate I*.

PLATE III

Penciling. *Plate III* should be laid out in the same manner as *Plate II*, that is, for size and border lines. In laying out the sixteen rectangles, however, the space between the center lines and rectangles must in every case be made ½ inch. Each rectangle is to be filled in with what is called *section lining*, illustrating the material of which the object is composed, and, therefore, differing accordingly. The conventions here shown are standard, and some of them will be used by the student in later work in Machine Drawing. Familiarity with them is of value to any draftsman. In drawing section lines of this character, the closeness of the lines should be governed by the area being sectioned. For large areas use a rather wide spacing; for small areas use a narrow spacing. In showing a section of any machine, the different parts are distinguished by altering the slope of the section lines, whether of the same material or not.

Draw the sixteen figures in full and then draw the border lines of the plate. Make the lettering conform to that in *Plate I* and *Plate II*.

Inking. After all the penciling of *Plate III* has been completed, the exercise should be inked, including the titles.

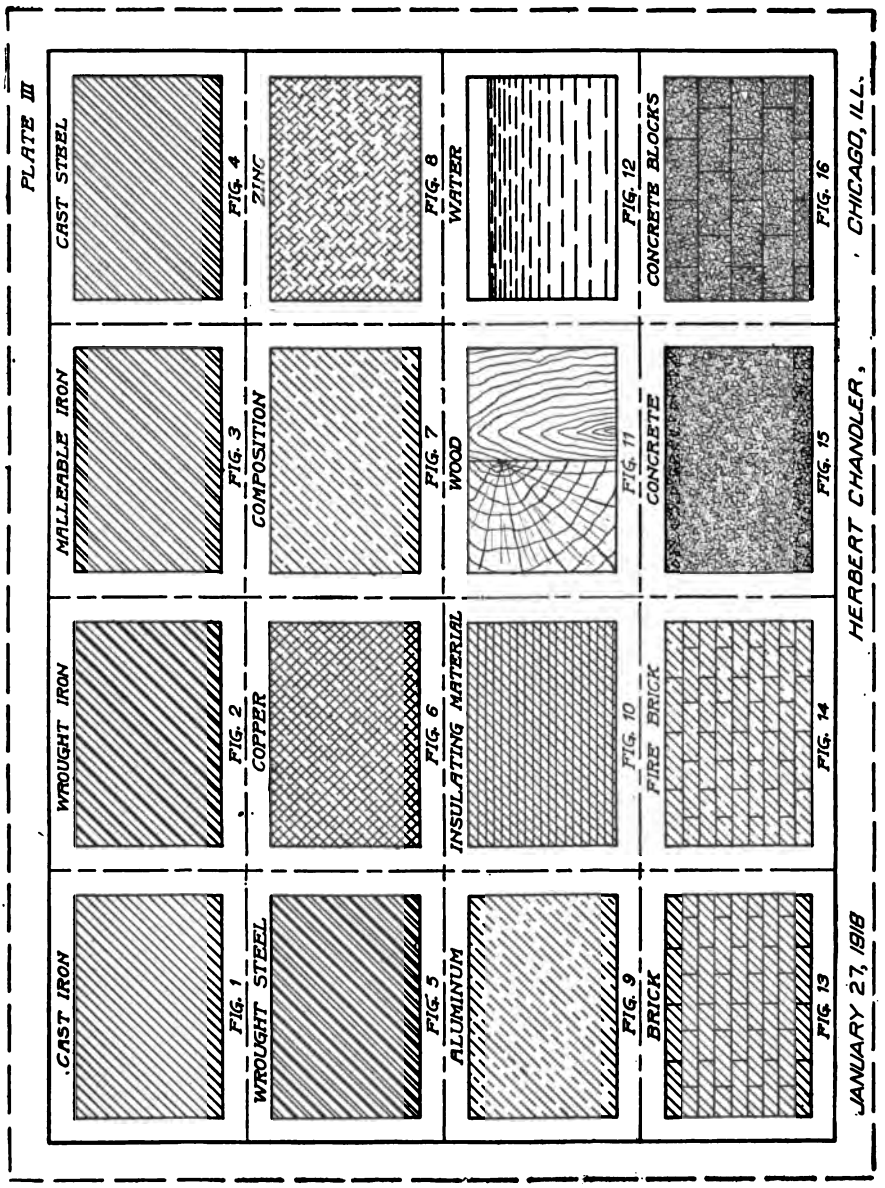
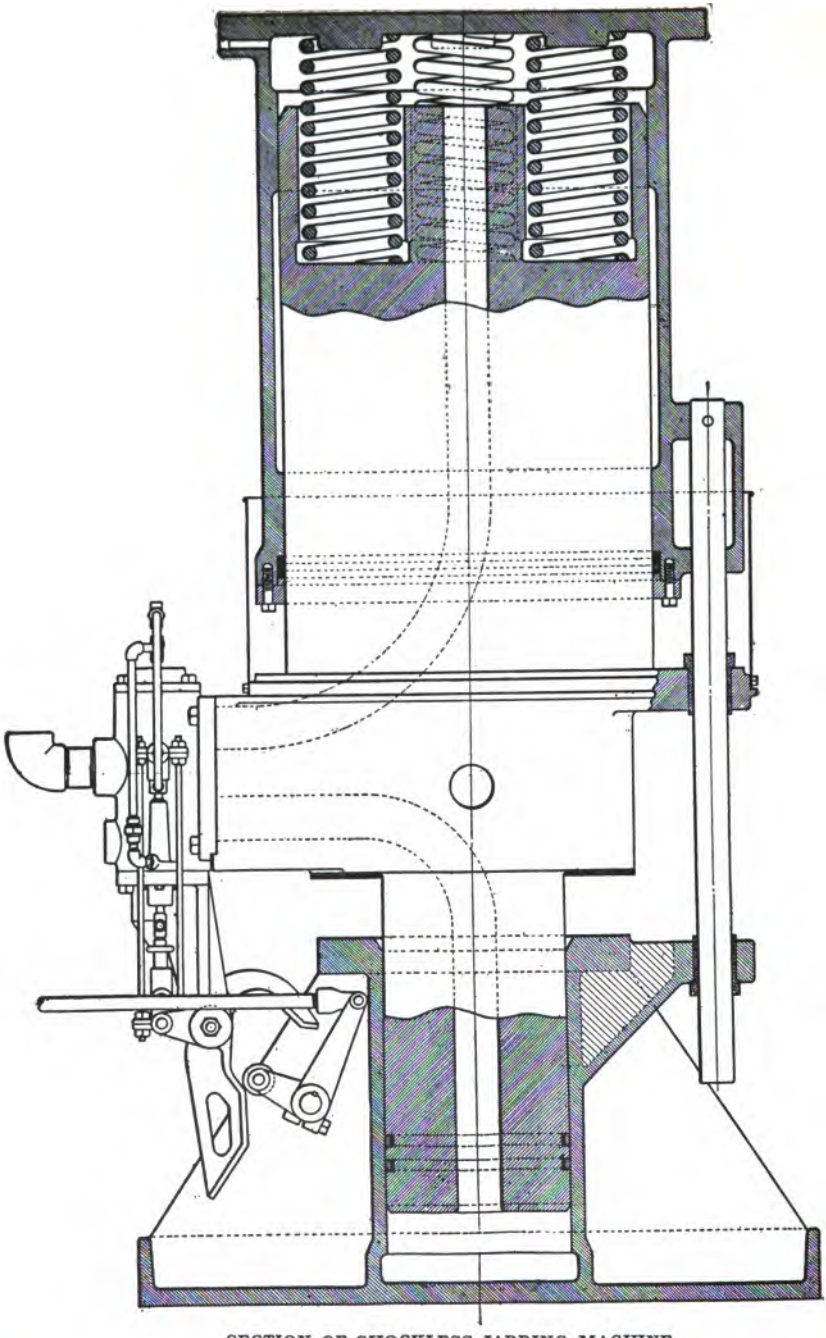


PLATE III
CAST IRON
FIG. 1
WROUGHT IRON
FIG. 2
MALLEABLE IRON
FIG. 3
CAST STEEL
FIG. 4
WROUGHT STEEL
FIG. 5
COPPER
FIG. 6
COMPOSITION
FIG. 7
ZINC
FIG. 8
ALUMINUM
FIG. 9
INSULATING MATERIAL
FIG. 10
WOOD
FIG. 11
WATER
FIG. 12
BRICK
FIG. 13
FIRE BRICK
FIG. 14
CONCRETE
FIG. 15
CONCRETE BLOCKS
FIG. 16
JANUARY 27, 1918
HERBERT CHANDLER, CHICAGO, ILL.



SECTION OF SHOCKLESS JARRING MACHINE

Courtesy of Tabor Manufacturing Company, Philadelphia, Pennsylvania

MECHANICAL DRAWING

PART II

In Part I the instructions and the problems worked out have been designed to teach the student the elementary operations of Mechanical Drawing, giving him a knowledge of the instruments, an ability to draw a straight and true line, and to make up simple figures. A fair degree of drawing ability is now assumed and we can pass on to more complicated problems. Wherever we turn for subjects, however, we find a knowledge of geometrical figures and their properties is absolutely essential to a clear understanding of the problems chosen and we will therefore turn to a discussion of these geometrical figures and the problems which involve them.

GEOMETRICAL DEFINITIONS

A *point* is used for marking position; it has neither length, breadth, nor thickness.

LINES

A *line* has length only; it is produced by the motion of a point.

A *straight line* or *right line* is one that has the same direction throughout. It is the shortest distance between two points.

A *curved line* is one that is constantly changing in direction. It is sometimes called a curve.

A *broken line* is one made up of several straight lines.

Parallel lines are lines which lie in the same plane and are equally distant from each other at all points.

A *horizontal line* is one having the direction of a line drawn upon the surface of water that is at rest. It is a line parallel to the horizon.

A *vertical line* is one that lies in the direction of a thread suspended from its upper end and having a weight at the lower end. It is a line that is perpendicular to a horizontal plane.

An *oblique line* is one that is neither vertical nor horizontal.

In Mechanical Drawing, lines drawn along the edge of the T-square, when the head of the T-square is resting against the left-hand edge of the board, are called *horizontal* lines. Those drawn at right angles or perpendicular to the edge of the T-square are called *vertical* lines.

If two lines cut each other, they are called *intersecting lines*, and the point at which they cross is called the *point of intersection.*

ANGLES

An *angle* is the measure of the difference in direction of two lines. The lines are called *sides*, and the point of meeting, the

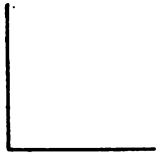


Fig. 40. Right Angle

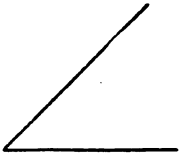


Fig. 41. Acute Angle

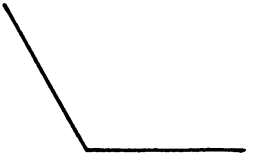


Fig. 42. Obtuse Angle

vertex. The size of an angle is independent of the length of the lines.

If one straight line meets another (extended if necessary), Fig. 40, so that the two angles thus formed are equal, the lines are said to be *perpendicular* to each other and the angles formed are called *right angles.*

An *acute angle* is less than a right angle, Fig. 41.

An *obtuse angle* is greater than a right angle, Fig. 42.

SURFACES

A *surface* is produced by the motion of a line; it has two dimensions—length and breadth.

A *plane figure* is a plane bounded on all sides by lines; the space included within these lines (if they are straight lines) is called a *polygon* or a *rectilinear figure.*

POLYGONS

A *polygon* is a plane figure bounded by straight lines. The boundary lines are called the *sides* and the sum of the sides is called the *perimeter.*

Polygons are classified according to the number of sides.

A *triangle* is a polygon of *three* sides.

A *quadrilateral* is a polygon of *four* sides.
A *pentagon* is a polygon of *five* sides, Fig. 43.
A *hexagon* is a polygon of *six* sides, Fig. 44.
A *heptagon* is a polygon of *seven* sides.
An *octagon* is a polygon of *eight* sides, Fig. 45.

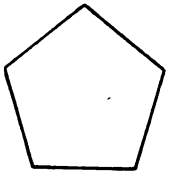


Fig. 43. Pentagon

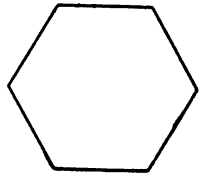


Fig. 44. Hexagon

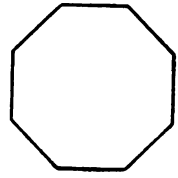


Fig. 45. Octagon

A *decagon* is a polygon of *ten* sides.
A *dodecagon* is a polygon of *twelve* sides.
An *equilateral* polygon is one all of whose sides are equal.
An *equiangular* polygon is one all of whose angles are equal.
A *regular* polygon is one all of whose angles and all of whose sides are equal.

Triangles. A triangle is a polygon enclosed by three straight lines called *sides*. The *angles* of a triangle are the angles formed by the sides.

A *right-angled* triangle, often called a *right* triangle, Fig. 46, is one that has a right angle. The longest side (the one opposite

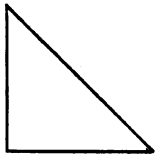


Fig. 46. Right-Angled Triangle

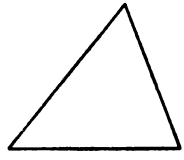


Fig. 47. Acute Angled Triangle

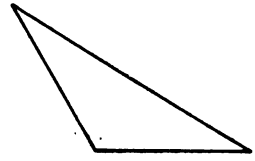


Fig. 48. Obtuse-Angled Triangle

the right angle) is called the *hypotenuse*, and the other sides are sometimes called *legs*.

An *acute-angled* triangle is one that has all of its angles acute, Fig. 47.

An *obtuse-angled* triangle is one that has an obtuse angle, Fig. 48.
An *equilateral* triangle is one having all of its sides equal, Fig. 49.
An *equiangular* triangle is one having all of its angles equal.

An *isosceles* triangle, Fig. 50, is one, two of whose sides are equal.

A *scalene* triangle, Fig. 51, is one, no two of whose sides are equal.

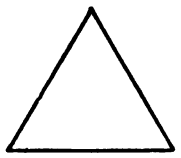


Fig. 49. Equilateral Triangle

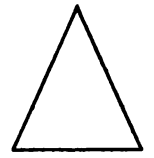


Fig. 50. Isosceles Triangle

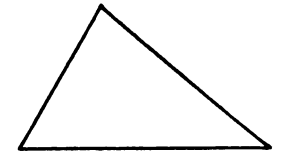


Fig. 51. Scalene Triangle

The base of a triangle is the lowest side; it is the side upon which the triangle is supposed to stand. Any side may, however, be taken as the base. In an isosceles triangle, the side which is not one of the equal sides is usually considered as the base.

The *altitude* of a triangle is the perpendicular drawn from the vertex to the base.

Quadrilaterals. A quadrilateral is a polygon bounded by four straight lines, as Fig. 52.

The *diagonal* of a quadrilateral is a straight line joining two opposite vertices.

Trapezium. A trapezium is a quadrilateral, no two of whose sides are parallel.

Trapezoid. A trapezoid is a quadrilateral having two sides

Fig. 52. Quadrilateral

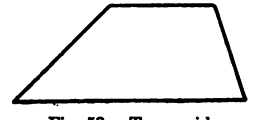


Fig. 53. Trapezoid

Fig. 54. Parallelogram

parallel, Fig. 53. The parallel sides are called the *bases* and the perpendicular distance between the bases is called the *altitude.*

Parallelogram. A parallelogram is a quadrilateral whose opposite sides are parallel, Fig. 54.

There are four kinds of parallelograms: rectangle, square, rhombus, and rhomboid.

The *rectangle,* Fig. 55, is a parallelogram whose angles are right angles.

The *square,* Fig. 56, is a parallelogram all of whose sides are equal and whose angles are right angles.

The *rhombus*, Fig. 57, is a parallelogram whose sides are equal but whose angles are not right angles.

Fig. 55. Rectangle

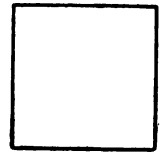


Fig. 56. Square

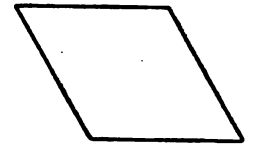


Fig. 57. Rhombus

The *rhomboid* is a parallelogram whose adjacent sides are unequal, and whose angles are not right angles.

CIRCLES

A *circle* is a plane figure bounded by a curved line called the *circumference*, every point of which is equally distant from a point within called the *center*, Fig. 58.

A *diameter* of a circle is a straight line drawn through the center, terminating at both ends in the circumference, Fig. 59.

A *radius* of a circle is a straight line joining the center with the

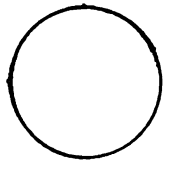


Fig. 58. Circle

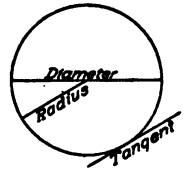


Fig. 59. Diameter, Radius, Tangent

Fig. 60. Quadrant

circumference. All radii of the same circle are equal and their length is always one-half that of the diameter.

An *arc* is any part of the circumference of a circle. An arc equal to one-half the circumference is called a *semi-circumference*, and an arc equal to one-quarter of the circumference is called a *quadrant*, Fig. 60. A quadrant may mean the arc or angle.

A *chord*, Fig. 61, is a straight line which joins the extremities of an arc but does not pass through the center of the circle.

A *secant* is a straight line which intersects the circumference in two points, Fig. 61.

A *segment* of a circle, Fig. 62, is the area included between an arc and a chord.

A *sector* is the area included between an arc and two radii drawn to the extremities of the arc, Fig. 62.

A *tangent* is a straight line which touches the circumference at only one point, called the *point of tangency or contact*, Fig. 59.

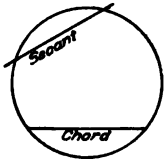


Fig. 61. Chord and Secant

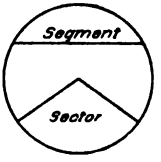


Fig. 62. Segment and Sector

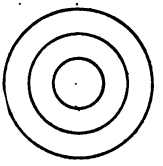


Fig. 63. Concentric Circles

Concentric circles are circles having the same center, Fig. 63.

An *inscribed angle* is an angle whose vertex lies in the circumference and whose sides are chords. It is measured by one-half the intercepted arc, Fig. 64.

A *central angle* is an angle whose vertex is at the center of the circle and whose sides are radii, Fig. 65.

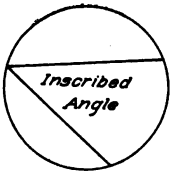


Fig. 64. Inscribed Angle

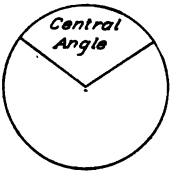


Fig. 65. Central Angle

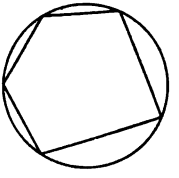


Fig. 66. Inscribed Polygon

An *inscribed polygon* is one whose vertices lie in the circumference and whose sides are chords, Fig. 66.

MEASUREMENT OF ANGLES

To measure an angle, take any convenient radius and describe an arc with the center at the vertex of the angle. The portion of the arc included between the sides of the angle is the *measure of the angle.* If the arc has a constant radius, the greater the divergence of the sides, the longer will be the arc. If there are several arcs drawn with the same center, the intercepted arcs will have different lengths but they will all be the *same fraction* of the entire circumference.

In order that the size of an angle or arc may be stated without saying that it is a certain fraction of a circumference, the circumference is divided into 360 equal parts called *degrees*, Fig. 67. Thus, it may be said that a certain angle contains 45 degrees, *i.e.*, it is $\frac{45}{360}=\frac{1}{8}$ of a circumference. In order to obtain accurate measurements each degree is divided into 60 equal parts called *minutes* and each minute into 60 equal parts called *seconds*.

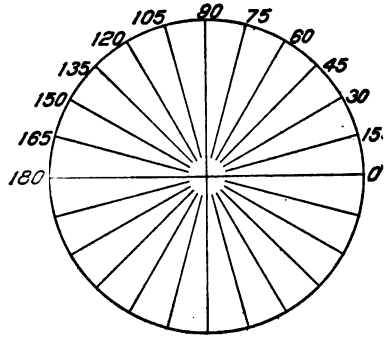


Fig. 67. Angular Measurement

SOLIDS

A *solid* has three dimensions—length, breadth, and thickness. The most common forms of solids are *polyhedrons*, *cylinders*, *cones*, and *spheres*.

POLYHEDRONS

A *polyhedron* is a solid bounded by planes. The bounding planes are called *faces* and their intersections are called *edges*. The intersections of the edges are called *vertices*.

A polyhedron having four faces is called a *tetrahedron;* one having six faces, a *hexahedron;* one having eight faces, and *octahedron*, Fig. 68; one having twelve faces, a *dodecahedron*, etc.

Prisms. A prism is a polyhedron having two opposite faces, called *bases*, which are equal and parallel, and other faces, called

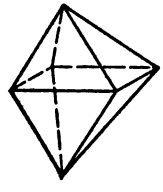


Fig. 68. Octahedron

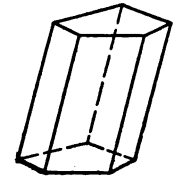


Fig. 69. Prism

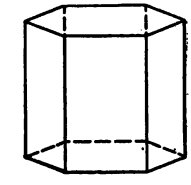


Fig. 70. Right Prism

lateral faces, which are parallelograms, Fig. 69. The *altitude* of a prism is the perpendicular distance between the bases. The area of the lateral faces is called the *lateral area*.

Prisms are called *triangular, rectangular, hexagonal,* etc., according to the shape of the bases. Further classifications are as follows:

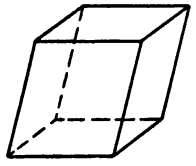


Fig. 71. Parallelopiped

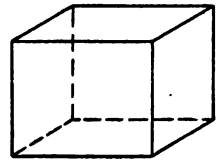


Fig. 72. Rectangular Parallelopiped

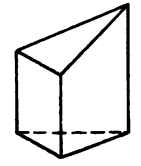


Fig. 73. Truncated Prism

A *right* prism is one whose lateral faces are perpendicular to the bases, Fig. 70.

A *regular* prism is a right prism having regular polygons for bases.

Parallelopiped. A parallelopiped is a prism whose bases are parallelograms, Fig. 71. If all the edges are perpendicular to the bases, it is called a *right parallelopiped.*

A *rectangular parallelopiped* is a right parallelopiped whose bases and lateral faces are rectangles, Fig. 72.

A *cube* is a rectangular parallelopiped all of whose faces are squares.

A *truncated prism* is the portion of a prism included between the base and a plane not parallel to the base, Fig. 73.

Pyramids. A pyramid is a polyhedron whose base is a polygon and whose lateral faces are triangles having a common vertex called the *vertex* of the pyramid.

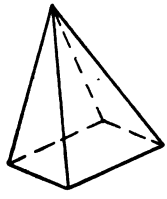


Fig. 74. Pyramid

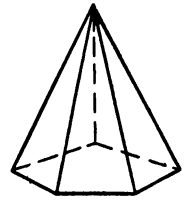


Fig. 75. Regular Pyramid

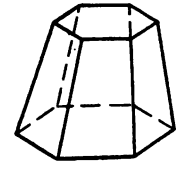


Fig. 76. Frustum of Pyramid

The *altitude* of the pyramid is the perpendicular distance from the vertex to the base.

Pyramids are named according to the kind of polygon forming the base, viz, *triangular, quadriangular,* Fig. 74. *pentagonal,* Fig. 75, *hexagonal.*

A *regular pyramid* is one whose base is a regular polygon and whose vertex lies in a perpendicular erected at the center of the base, Fig. 75.

A *truncated* pyramid is the portion of a pyramid included between the base and a plane not parallel to the base.

A *frustum* of a pyramid is the solid included between the base and a plane parallel to the base, Fig. 76; its *altitude* is the perpendicular distance between the bases.

CYLINDERS

A *cylinder* is a solid having as bases two equal parallel surfaces bounded by curved lines, and as its lateral face the continuous

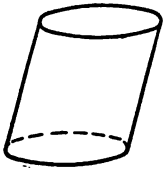


Fig. 77. Cylinder

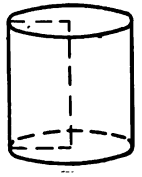


Fig. 78. Right Cylinder

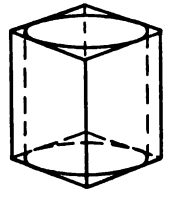


Fig. 79. Inscribed Cylinder

surface generated by a straight line connecting the bases and moving along their circumferences. The bases are usually circles and such a cylinder is called a *circular cylinder*, Fig. 77.

A *right cylinder*, Fig. 78, is one whose side is perpendicular to the bases.

The *altitude* of a cylinder is the perpendicular distance between the bases.

A prism whose base is a regular polygon may be inscribed in or circumscribed about a circular cylinder, Fig. 79.

CONES

A *cone* is a solid bounded by a conical surface and a plane which cuts the conical surface. It may be considered as a pyramid with an infinite number of sides, Fig. 80.

The conical surface is called the *lateral area* and it tapers to a point called the *vertex;* the plane is called the *base.*

The *altitude* of a cone is the perpendicular distance from the vertex to the base.

An *element of a cone* is any straight line from the vertex to the circumference of the base.

A *circular cone* is a cone whose base is a circle.

A *right circular cone,* or *cone of revolution,* Fig. 81, is a cone

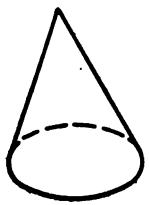


Fig. 80. Cone

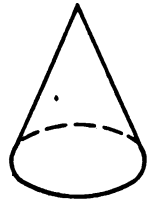


Fig. 81. Right Circular Cone

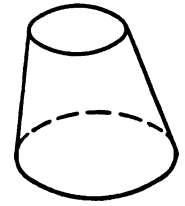


Fig. 82. Frustum of Cone

whose axis is perpendicular to the base. It may be generated by the revolution of a right triangle about one of the legs as an axis.

A *frustum* of a cone, Fig. 82, is the portion of the cone included between the base and a plane parallel to the base; its *altitude* is the perpendicular distance between the bases.

SPHERES

A *sphere* is a solid bounded by a curved surface, every point of which is equally distant from a point within called the *center.*

The *diameter* is a straight line drawn through the center and having its extremities in the curved surface. The *radius*—½ diameter—is the straight line from the center to a point on the surface.

A *plane is tangent to a sphere* when it touches the sphere in only

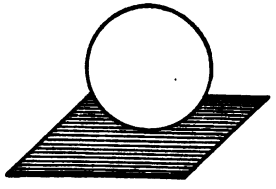


Fig. 83. Plane Tangent to Sphere

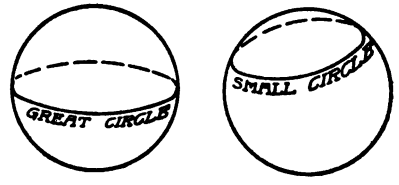


Fig. 84. Great and Small Circle

one point. A plane perpendicular to a radius at its outer extremity is tangent to the sphere, Fig. 83.

An *inscribed polyhedron* is a polyhedron whose vertices lie in the surface of the sphere.

A *circumscribed polyhedron* is a polyhedron whose faces are tangent to a sphere.

A *great circle* is the intersection of the spherical surface and a plane passing through the center of the sphere, Fig. 84.

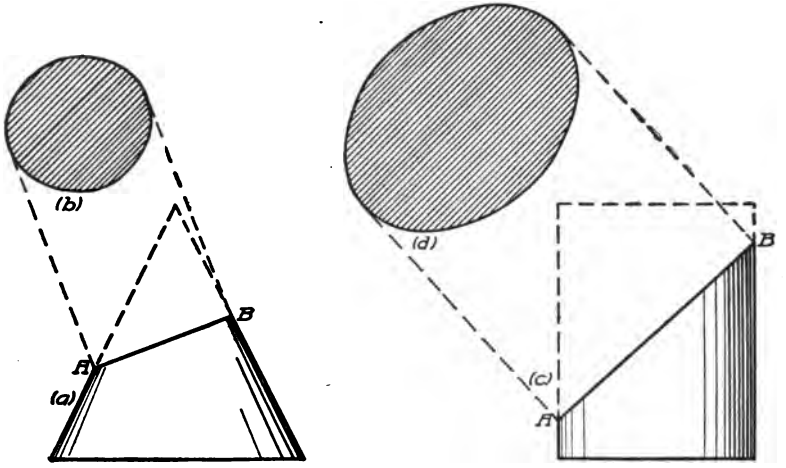


Fig. 85. Intersections of Plane with Cone and Cylinder Giving Ellipses as Shown in (*b*) and (*d*)

A *small circle* is the intersection of the spherical surface and a plane which does not pass through the center, Fig. 84.

CONIC SECTIONS

If a plane intersects a cone at various angles with the base the geometrical figures thus formed are called *conic sections*. A plane perpendicular to the base passing through the vertex of a right circular cone forms an isosceles triangle. If the plane is parallel to the base, the intersection of the plane and the conical surfaces will be the circumference of a circle.

Ellipse. If a plane AB, Fig. 85a, cuts a cone oblique to the axis of the cone, but not cutting the base, the curve formed is called an ellipse, as shown in Fig. 85b, this view being taken perpendicular to the plane AB. If the plane cuts a cylinder as shown in Fig. 85c, the ellipse shown in Fig. 85d is the result, this view being also taken perpendicular to the plane AB. An ellipse may be defined as *a curve generated by a point*

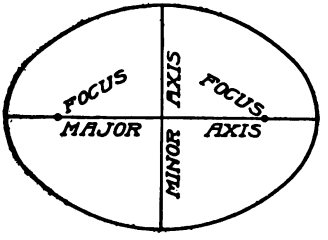


Fig. 86. Diagram Showing Constants of Ellipse

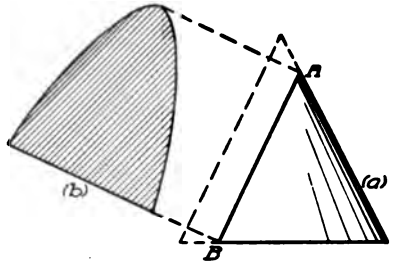


Fig. 87. Intersection of Plane with Cone, Parallel to Element of Cone and Parabolic Section Produced

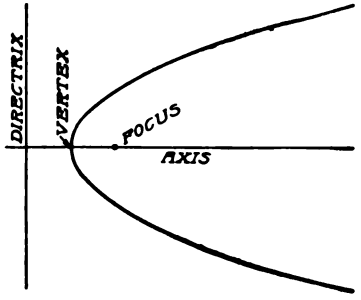


Fig. 88. Diagram Showing Constants of Parabola

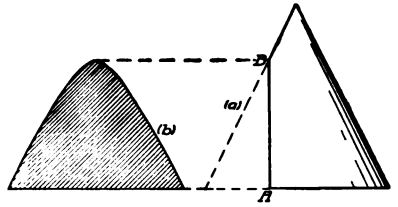


Fig. 89. Intersection of Plane with Cone, Parallel to Axis and Hyperbolic Section Produced

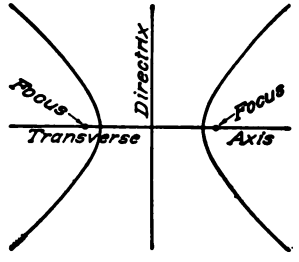


Fig. 90. Diagram Showing Constants of Hyperbola

moving in a plane in such a manner that the sum of the distances from the point to two fixed points shall always be constant.

The two fixed points are called *foci*, Fig. 86, and shall lie on the longest line that can be drawn in the ellipse which is called the *major axis;* the shortest line is called the *minor axis;* and is perpendicular to the major axis at its middle point, called the *center.*

An ellipse may be constructed if the major and minor axes are given or if the foci and one axis are known.

Parabola. If a plane AB, Fig. 87a, cuts a cone parallel to an element of the cone, the curve resulting from this intersection is called a parabola, as shown in Fig. 87b, the view being taken perpendicular to the plane AB. This curve is not a closed curve for the branches approach parallelism.

A parabola may be defined as *a curve every point of which is equally distant from a line and a point.*

The point is called the *focus*, Fig. 88, and the given line, the *directrix.* The line perpendicular to the directrix and passing through the focus is the *axis.* The intersection of the axis and the curve is the *vertex.*

Hyperbola. If a plane AB, Fig. 89a, cuts a cone parallel to its axis, the resulting curve is called a hyperbola,

Fig. 89b, the view being taken perpendicular to the plane AB.

Like the parabola, the curve is not closed, the branches constantly diverging.

A hyperbola is defined as *a plane curve such that the difference between the distances from any point in the curve to two fixed points is equal to a given distance.*

The two fixed points are the *foci* and the line passing through them is the *transverse axis,* Fig. 90.

Rectangular Hyperbola. The form of hyperbola most used in Mechanical Engineering is called the rectangular hyperbola because it is drawn with reference to rectangular coördinates. This curve is constructed as follows: In Fig. 91, OX and OY are the two coördinate axes drawn at right angles to each other. These lines are also called *asymptotes.* Assume A to be a known point on the curve. Draw AC parallel to OX and AD' perpendicular to OX. Mark off any convenient points on AC such as E, F, G, and H, and through these points draw EE', FF', GG', and HH', perpendicular to OX. Connect E, F, G, H, and C with O. Through the points of intersection of the oblique lines and the vertical line AD' draw the horizontal lines LL', MM', NN', PP', and QQ'. The first point on the curve is the assumed point A, the second point is R, the intersection of LL' and EE', the third the intersection S, and so on.

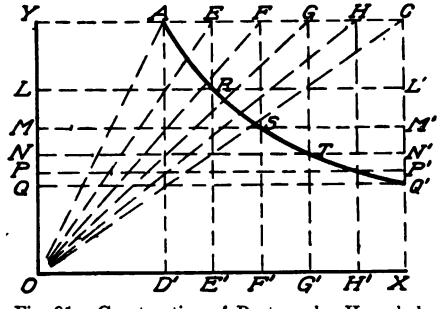


Fig. 91. Construction of Rectangular Hyperbola

In this curve the products of the coördinates of all points are equal. Thus $LR \times RE' = MS \times SF' = NT \times TG'$.

ODONTOIDAL CURVES

Cycloidal Curves. *Cycloid.* The cycloid is a curve generated by a point on the circumference of a circle which rolls on a straight line tangent to the circle, as shown at the left, Fig. 92.

The rolling circle is called the *describing* or *generating circle,* the point on the circle, the *describing* or *generating point,* and the

tangent along which the circle rolls, the *director*. In order that the curve described by the point may be a true cycloid the circle must roll without any slipping.

Hypocycloid. In case the generating circle rolls upon the inside of an arc or circle, the curve thus generated is a hypocycloid,

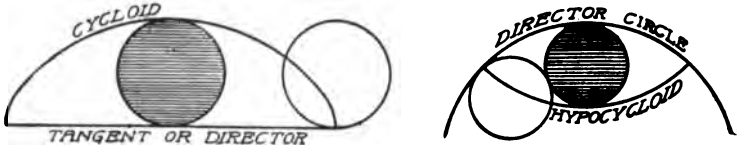


Fig. 92. Geometrical Constructions for Cycloid and Hypocycloid

Fig. 92. If the generating circle has a diameter equal to the radius of the director circle the hypocycloid becomes a straight line.

Epicycloid. If the generating circle rolls upon the *outside* of the *director circle*, the curve generated is an epicycloid, Fig. 93.

Involute Curves. If a thread of fine wire is wound around a cylinder or circle and then unwound, the end will describe an involute curve. The involute may be defined as *a curve generated by a point in a tangent rolling on a circle, known as the base circle*, Fig. 94.

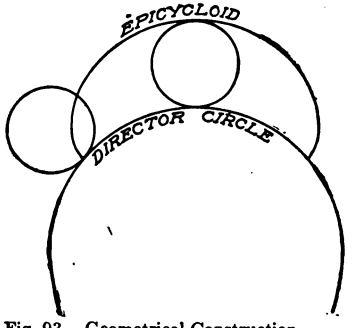


Fig. 93. Geometrical Construction for an Epicycloid

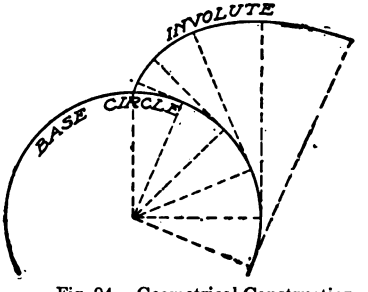


Fig. 94. Geometrical Construction for an Involute

The details of the ellipse, parabola, hyperbola, cycloid, and involute will be taken up in connection with the plates.

The most important application of the cycloidal and involute curves is in the cutting of all forms of gear teeth. It has been found that the teeth of gears when cut accurately to either of these curves will mesh with the least friction and run with exceptional smoothness. The development of these gears and of the machines for cutting them has reached a high state of perfection.

GEOMETRICAL PROBLEMS

The problems given in Plates IV to VIII inclusive have been chosen because of their particular bearing on the work of the mechanical draftsman. They should be solved with great care, as the principles involved will be used in later work.

PLATE IV

Penciling. The horizontal and vertical center lines and the border lines should be laid out in the same manner as in *Plate I.* Now measure off $2\frac{1}{4}$ inches on both sides of the vertical center line and through these points draw vertical lines as shown by the dot and dash lines, *Plate IV.* In locating the figures, place them a little above the center so that there will be room for the number of the problem.

Draw in lightly the lines of each figure with pencil and after the entire plate is completed, ink them. In penciling, all intersections must be formed with great care as the accuracy of the results depends upon it. Keep the pencil points in good order at all times and draw lines *exactly* through intersections.

Problem 1. *To bisect a given straight line.*

Draw the horizontal straight line $A\,C$ about 3 inches long. With the extremity A as a center and any convenient radius—about 2 inches—describe arcs above and below the line $A\,C$. With the other extremity C as a center and with the same radius draw similar arcs intersecting the first arcs at D and E. The radius of these arcs must be greater than one-half the length of the line in order that they may intersect. Now draw the straight line $D\,E$ passing through the intersections D and E. This line will cut $A\,C$ at its middle point F.

Therefore

$$A\,F = F\,C$$

Proof. Since the points D and E are equally distant from A and C a straight line drawn through them is perpendicular to $A\,C$ at its middle point F.

Problem 2. *To construct an angle equal to a given angle.*

Draw the line $O\,C$ about 2 inches long and the line $O\,A$ of about the same length. The angle formed by these lines may be

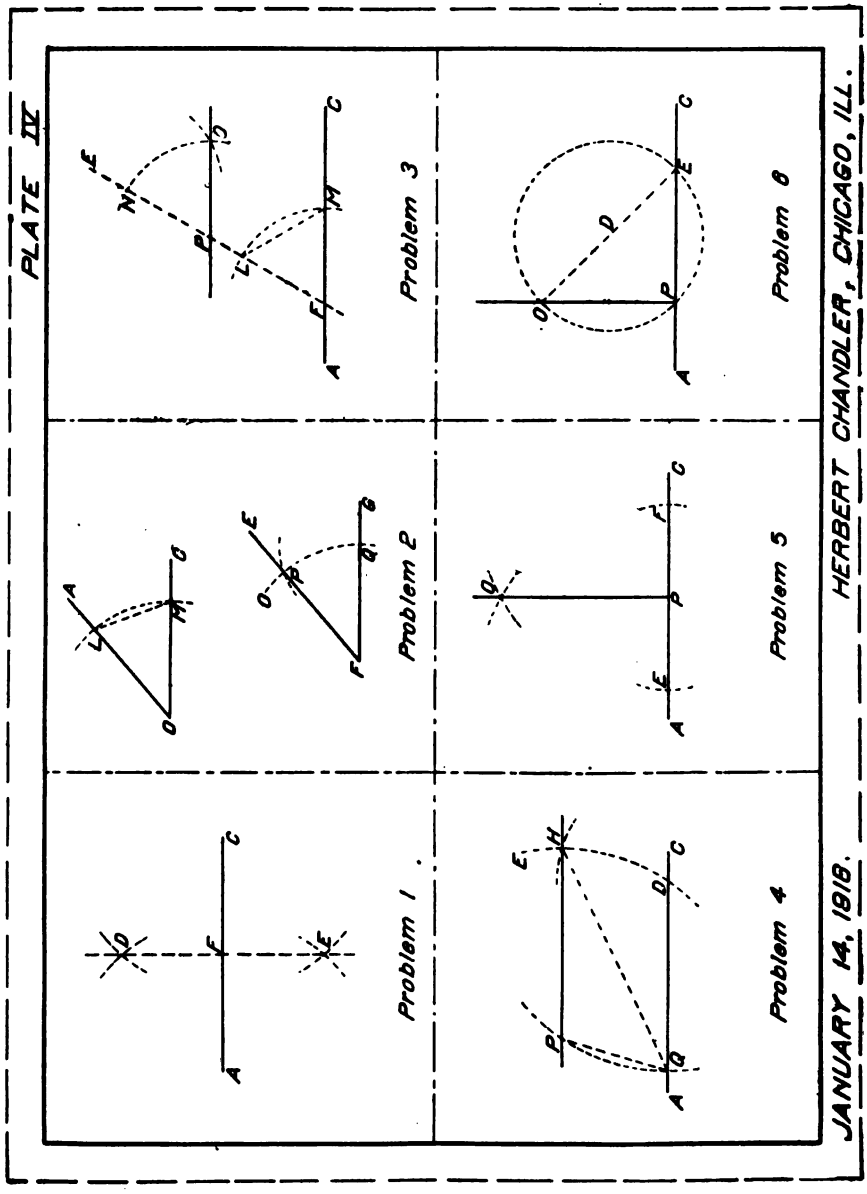


PLATE III
Problem 1
Problem 2
Problem 3
Problem 4
Problem 5
Problem 6
JANUARY 14, 1918.
HERBERT CHANDLER, CHICAGO, ILL.

any convenient size—about 45 degrees is suitable. This angle $A\ O\ C$ is the given angle.

Now draw $F\ G$, a horizontal line about $2\frac{1}{4}$ inches long, and let F, the left-hand extremity, be the vertex of the angle to be constructed.

With O as a center and any convenient radius—about $1\frac{1}{2}$ inches—describe the arc $L\ M$ cutting both $O\ A$ and $O\ C$. With F as a center and the same radius draw the indefinite arc $O\ Q$. Now set the compass so that the distance between the pencil and the needle point is equal to the chord $L\ M$. With Q as a center and a radius equal to $L\ M$ draw an arc cutting the arc $O\ Q$ at P. Through F and P draw the straight line $F\ E$. The angle $E\ F\ G$ is the required angle since it is equal to $A\ O\ C$.

Proof. Since the chords of the arcs $L\ M$ and $P\ Q$ are equal, the arcs are equal. The angles are equal because with equal radii equal arcs are intercepted by equal angles.

Problems 3 and 4. *To draw through a given point a line parallel to a given line.*

First Method. Draw the straight line $A\ C$ about $3\frac{1}{2}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. Through the point P draw an oblique line $F\ E$ forming any convenient angle—about 60 degrees—with $A\ C$. Now construct an angle equal to $P\ F\ C$ having its vertex at P and the line $E\ P$ as one side. (See Problem 2.) The straight line $P\ O$ forming the other side of the angle $E\ P\ O$ will be parallel to $A\ C$.

Proof. If two straight lines are cut by a third making the corresponding angles equal, the lines are parallel.

Second Method. Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long and assume the point P about $1\frac{1}{2}$ inches above $A\ C$. With P as a center and any convenient radius—about $2\frac{1}{2}$ inches—draw the indefinite arc $E\ D$ cutting the line $A\ C$. Now with the same radius and with D as a center, draw an arc $P\ Q$. Set the compass so that the distance between the needle point and the pencil is equal to the chord $P\ Q$. With D as a center and a radius equal to $P\ Q$, describe an arc cutting the arc $E\ D$ at H. A line drawn through P and H will be parallel to $A\ C$.

Proof. Draw the line $Q\ H$. Since the arcs $P\ Q$ and $H\ D$ are equal and have the same radii, the angles $P\ H\ Q$ and $H\ Q\ D$

are equal. Two lines are parallel if the alternate interior angles are equal.

Problems 5 and 6. *To draw a perpendicular to a line from a point in the line.*

First Method. WHEN THE POINT IS NEAR THE MIDDLE OF THE LINE.

Draw the line $A\,C$ about $3\frac{1}{2}$ inches long and assume the point P near the middle of the line. With P as a center and any convenient radius—about $1\frac{1}{4}$ inches—draw two arcs cutting the line $A\,C$ at E and F. Now with E and F as centers and any convenient radius —about $2\frac{1}{2}$ inches—describe arcs intersecting at O. The line $O\,P$ will be perpendicular to $A\,C$ at P.

Proof. The points P and O are both equally distant from E and F. Hence a line drawn through them is perpendicular to $E\,F$ at P.

Second Method. WHEN THE POINT IS NEAR THE END OF THE LINE.

Draw the line $A\,C$ about $3\frac{1}{2}$ inches long. Assume the given point P to be about $\frac{3}{4}$ inch from the end A. With any point D as a center and a radius equal to $D\,P$, describe an arc cutting $A\,C$ at E. Through E and D draw the diameter $E\,O$. A line from O to P is perpendicular to $A\,C$ at P.

Proof. The angle $O\,P\,E$ is inscribed in a semicircle; hence it is a right angle, and the sides $O\,P$ and $P\,E$ are perpendicular to each other.

Lettering. After completing these figures draw pencil lines for the lettering. Place the words *"Plate IV"* and the date and the name in the border, as in preceding plates. To letter the words "Problem 1," "Problem 2," etc., draw three horizontal lines $\frac{1}{4}$ inch, $\frac{3}{8}$ inch, and $\frac{7}{16}$ inch, respectively, above the horizontal center line and the lower border line to serve as a guide for the size of the letters.

Inking. In inking *Plate IV*, ink in the figures first. Make the line $A\,C$, Problem 1, a full line as it is the given line; make the arcs and the line $D\,E$ dotted as they are construction lines. Similarly in Problem 2, make the sides of the angles full lines and the chord $L\,M$ and the arcs dotted. Follow the same plan in inking the lines of Problems 3, 4, 5, and 6. In Problem 6, ink in only that part of the circumference which passes through the points O, P, and E.

After inking the figures, ink in the heavy border line, and the lettering.

PLATE V

Penciling. In laying out the border lines and center lines follow the directions given for *Plate IV*. Draw the dot and dash lines in the same manner, as there are to be six problems on this plate.

Problem 7. *To draw a perpendicular to a line from a point without the line.*

Draw the straight line $A\ C$ about $3\frac{1}{4}$ inches long, and assume the point P about $1\frac{1}{2}$ inches above the line. With P as a center and any convenient radius—about 2 inches—describe an arc cutting $A\ C$ at E and F. The radius of this arc must always be such that it will cut $A\ C$ in two points; the nearer the points E and F are to A and C, the greater will be the accuracy of the work.

Now with E and F as centers and any convenient radius—about $2\frac{1}{4}$ inches—draw the arcs intersecting below $A\ C$ at T. A line through the points P and T will be perpendicular to $A\ C$. In case there is not room below $A\ C$ to draw the arcs, they may be drawn intersecting above the line as shown at N. Whenever convenient draw the arcs below $A\ C$ for greater accuracy.

Proof. Since P and T are both equally distant from E and F, the line $P\ T$ is perpendicular to $A\ C$.

Problems 8 and 9. *To bisect a given angle.*

First Method. WHEN THE SIDES INTERSECT.

Draw the lines $O\ C$ and $O\ A$—about 3 inches long—forming any angle of 45 to 60 degrees. With O as a center and any convenient radius—about 2 inches—draw an arc intersecting the sides of the angle at E and F. With E and F as centers and a radius of $1\frac{1}{2}$ or $1\frac{3}{4}$ inches, describe short arcs intersecting at I. A line $O\ D$, drawn through the points O and I, bisects the angle.

In solving this problem the arc $E\ F$ should not be too near the vertex if accuracy is desired.

Proof. The central angles $A\ O\ D$ and $D\ O\ C$ are equal because the arc $E\ F$ is bisected by the line $O\ D$. The point I is equally distant from E and F.

Second Method. WHEN THE LINES DO NOT INTERSECT.

Draw the lines $A\ C$ and $E\ F$ about 4 inches long making an

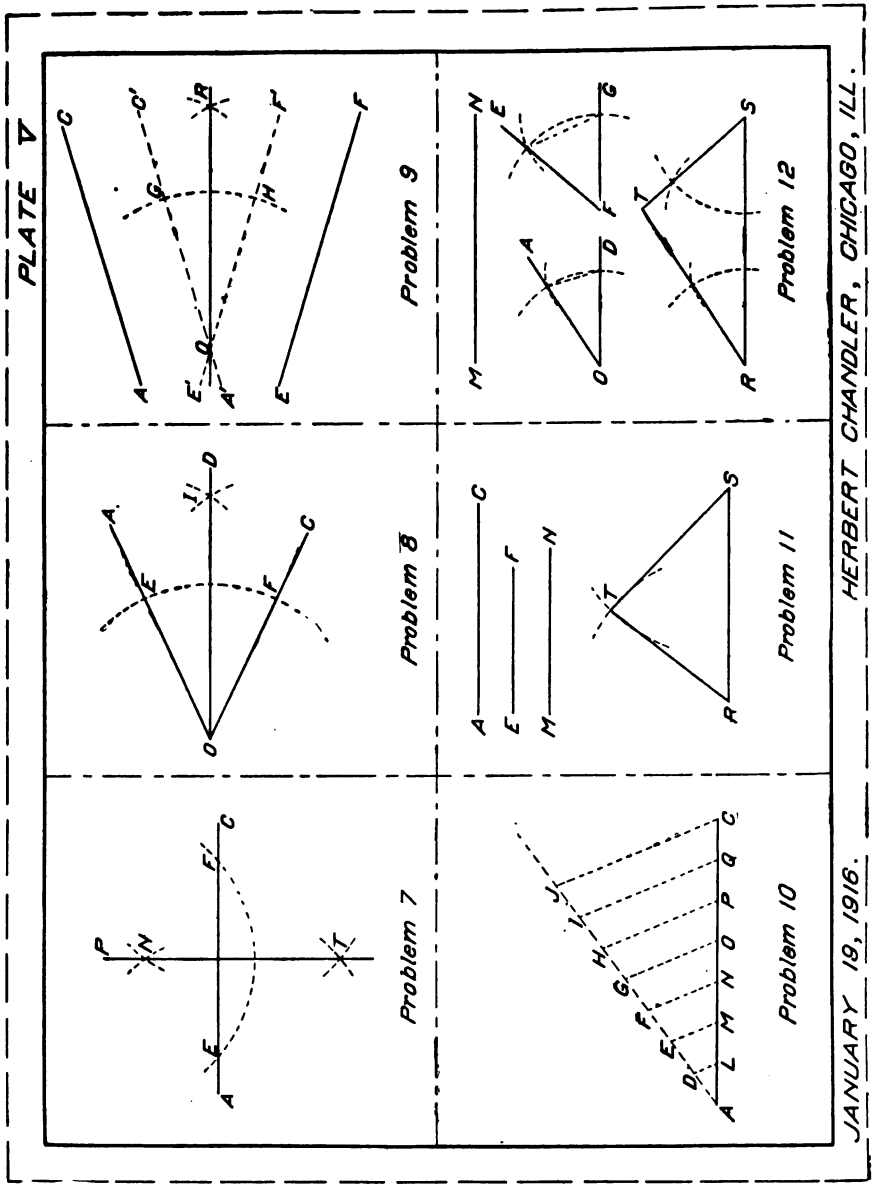


PLATE V
Problem 7
Problem 8
Problem 9
Problem 10
Problem 11
Problem 12
HERBERT CHANDLER, CHICAGO, ILL.
JANUARY 19, 1916.

angle approximately as shown. Draw $A'\ C'$ and $E'\ F'$ parallel to $A\ C$ and $E\ F$ and at such equal distances from them that they will intersect at O. Now bisect the angle $C'\ O\ F'$ by the method given in Problem 8. The line $O\ R$ bisects the given angle.

Proof. Since $A'\ C'$ is parallel to $A\ C$ and $E'\ F'$ is parallel to $E\ F$, the angle $C'\ O\ F'$ is equal to the angle formed by the lines $A\ C$ and $E\ F$. Hence as $O\ R$ bisects angle $C'\ O\ F'$ it also bisects the angle formed by the lines $A\ C$ and $E\ F$.

Problem 10. *To divide a line into any number of equal parts.*

Let $A\ C$—about $3\frac{3}{4}$ inches long—be a given line. Suppose it is desired to divide it into 7 equal parts. First draw the line $A\ J$ at least 4 inches long, forming any convenient angle with $A\ C$. On $A\ J$ lay off, by means of the dividers or scale, points D, E, F, G, etc., each $\frac{1}{2}$ inch apart. (If dividers are used, the spaces need not be exactly $\frac{1}{2}$ inch.) Draw the line $J\ C$ and through the points D, E, F, G, etc., draw lines parallel to $J\ C$. These parallels will divide the line $A\ C$ into 7 equal parts.

Proof. If a series of parallel lines, cutting two straight lines, intercept equal distances on one of these lines, they also intercept equal distances on the other.

Problem 11. *To construct a triangle having given the three sides.*

Draw the three sides, $A\ C$, $2\frac{3}{4}$ inches long; $E\ F$, $1\frac{5}{16}$ inches long; and $M\ N$, $2\frac{8}{16}$ inches long.

Draw $R\ S$ equal in length to $A\ C$. With R as a center and a radius equal to $E\ F$ describe an arc. With S as a center and a radius equal to $M\ N$ draw an arc cutting the arc previously drawn, at T. Connect T with R and S to form the triangle.

Problem 12. *To construct a triangle having given one side and the two adjacent angles.*

Draw the line $M\ N$ $3\frac{1}{4}$ inches long and draw two angles $A\ O\ D$ and $E\ F\ G$ about 30 degrees and 60 degrees respectively.

Draw $R\ S$ equal in length to $M\ N$ and with R as a vertex and $R\ S$ as one side construct an angle equal to $A\ O\ D$. In a similar manner construct at S an angle equal to $E\ F\ G$. Draw lines from R and S through the two established points until they meet at T. The triangle $R\ T\ S$ will be the required triangle.

Lettering. Draw the pencil lines and put in the lettering as in plates already drawn.

Inking. In inking *Plate V*, follow the principles previously used and do not make certain lines dotted until sure that they should be dotted.

After inking the figures, ink in the border lines and the lettering as already explained.

PLATE VI

Penciling. Lay out this plate in the same manner as the preceding plates.

Problem 13. *To describe an arc or circumference through three given points not in the same straight line.*

Locate the three points A, B, and C with a distance between A and B of about 2 inches and a distance between A and C of about $2\frac{1}{4}$ inches. Connect A and B and A and C. Erect perpendiculars to the middle points of $A\,B$ and $A\,C$ as explained in Problem 1. Now draw light pencil lines connecting the intersections I and J and E and F. These lines will intersect at O.

With O as a center and a radius equal to the distance $O\,A$, describe the circumference passing through A, B, and C.

Proof. The point O is equally distant from A, B, and C, since it lies in the perpendiculars to the middle points of $A\,B$ and $A\,C$. Hence the circumference will pass through A, B, and C.

Problem 14. *To inscribe a circle in a given triangle.*

Draw the triangle $L\,M\,N$ of any convenient size. $M\,N$ may be made $3\frac{1}{4}$ inches, $L\,M$, $2\frac{3}{4}$ inches, and $L\,N$, $3\frac{1}{2}$ inches. Bisect the angles $M\,L\,N$ and $L\,M\,N$ by the method used in Problem 8. The bisectors $M\,I$ and $L\,J$ intersect at O, which is the center of the inscribed circle. The radius of the circle is equal to the perpendicular distance from O to one of the sides.

Proof. The point of intersection of the bisectors of the angles of a triangle is equally distant from the sides.

Problem 15. *To inscribe a regular pentagon in a given circle.*

With O as a center and a radius of about $1\frac{1}{2}$ inches, describe the given circle. With the T-square and triangles draw the center lines $A\,C$ and $E\,F$ perpendicular to each other and passing through O. Bisect one of the *radii*, $O\,C$, at H and with this point as a center and a radius $H\,E$, describe the arc $E\,P$. This arc cuts the diameter $A\,C$ at P. With E as a center and a radius $E\,P$, draw arcs cutting

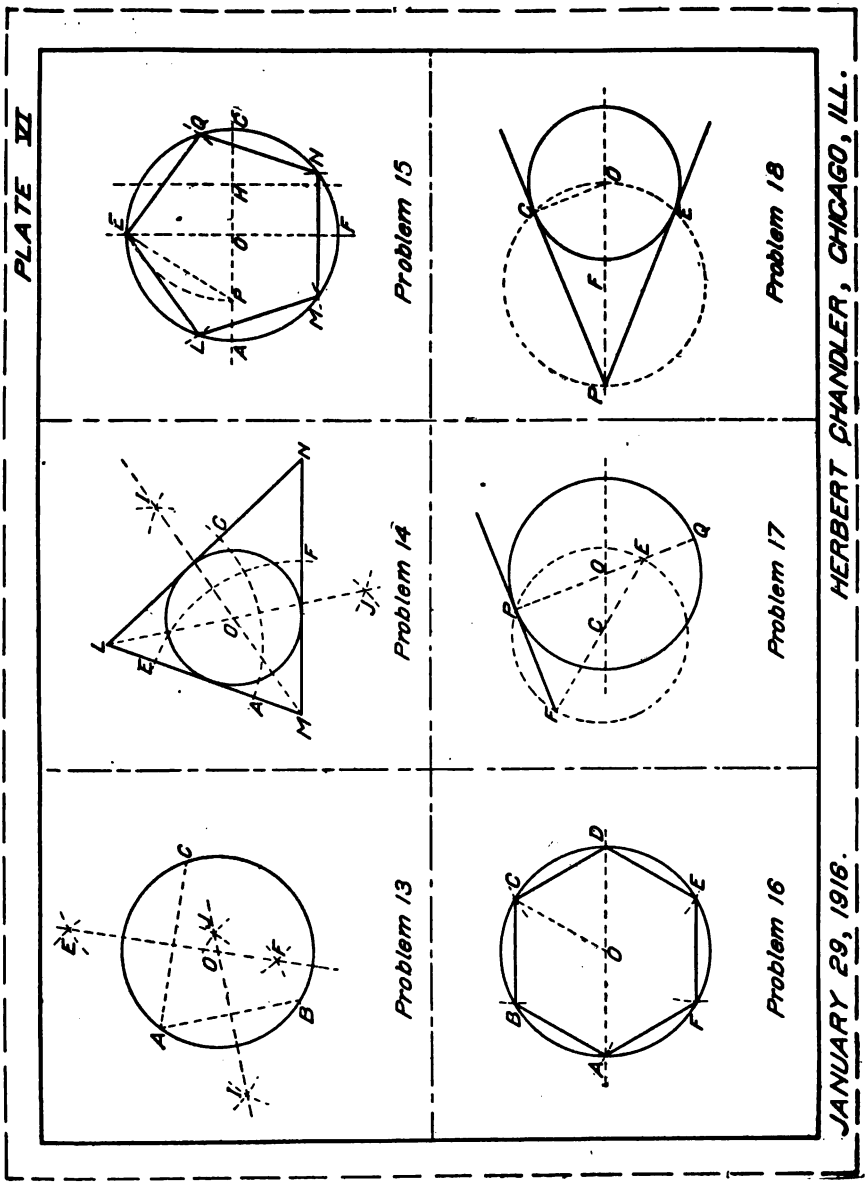


PLATE XII
Problem 15
Problem 18
Problem 14
Problem 17
Problem 13
Problem 16
JANUARY 29, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

the circumference at L and Q. With the same radius and centers at L and Q, draw the arcs cutting the circumference at M and N.

The pentagon is completed by drawing the chords $E\,L$, $L\,M$, $M\,N$, $N\,Q$, and $Q\,E$.

Problem 16. *To inscribe a regular hexagon in a given circle.*

With O as a center and a radius of $1\frac{3}{8}$ inches draw the given circle. With the T-square draw the diameter $A\,D$. With D as a center, and a radius equal to $O\,D$, describe arcs cutting the circumference at C and E. Now with C and E as centers and the same radius, draw the arcs, cutting the circumference at B and F. Draw the hexagon by joining the points thus formed.

Therefore, in order to inscribe a regular hexagon in a circle, mark off chords equal in length to the radius.

To inscribe an equilateral triangle in a circle the same method may be used, the triangle being formed by joining the opposite vertices of the hexagon.

Proof. Since the triangle $O\,C\,D$ is an equilateral triangle by construction, the angle $C\,O\,D$ is one-third of two right angles and one-sixth of four right angles. Hence arc $C\,D$ is one-sixth of the circumference and the chord is a side of a regular hexagon.

Problem 17. *To draw a line tangent to a circle at a given point on the circumference.*

With O as a center and a radius of about $1\frac{1}{4}$ inches draw the given circle. Assume some point P on the circumference and join the point P with the center O. By the method given in Problem 6, *Plate IV*, construct a perpendicular to $P\,O$, which perpendicular will be the desired tangent to the circle at the point P.

Proof. A line perpendicular to a radius at its extremity is tangent to the circle.

Problem 18. *To draw a line tangent to a circle from a point outside the circle.*

With O as a center and a radius of about 1 inch draw the given circle. Assume P some point outside of the circle about $2\frac{1}{2}$ inches from the center. Draw a straight line passing through P and O. Bisect $P\,O$ and with the middle point F as a center describe the circle passing through P and O. Draw a line from P through the intersection of the two circumferences C. The line $P\,C$ is tangent to the given circle. Similarly $P\,E$ is tangent to the circle.

Proof. The angle $P\ C\ O$ is inscribed in a semicircle and hence is a right angle. Since $P\ C\ O$ is a right angle, $P\ C$ is perpendicular to $C\ O$. The perpendicular to a radius at its extremity is tangent to the circumference.

Inking. In inking *Plate VI*, the same method should be followed as in previous plates.

PLATE VII

Penciling. Lay out this plate in the same manner as the preceding plates.

Problems 19 and 20. *To draw an ellipse when the axes are given.*

First Method. Draw the lines $L\ M$ and $C\ D$ about $3\frac{1}{4}$ and $2\frac{1}{4}$ inches long respectively, making $C\ D$ perpendicular to $L\ M$ at its middle point P and having $C\ P = P\ D$. The two lines, $L\ M$ and $C\ D$, are the axes. With C as a center and a radius $L\ P$ equal to one-half the major axis, draw the arc, cutting the major axis at E and F. These two points are the foci.

Now locate several points on $P\ M$, such as A, B, and G. With E as a center and a radius equal to $L\ A$, draw arcs above and below $L\ M$. With F as a center and a radius equal to $A\ M$ describe short arcs cutting those already drawn as shown at N. With E as a center and a radius equal to $L\ B$ draw arcs above and below $L\ M$ as before. With F as a center and a radius equal to $B\ M$, draw arcs intersecting those already drawn as shown at O. The point R and others are found by repeating the process. The student is advised to find at least 12 points on the curve—6 above and 6 below $L\ M$. These 12 points with L, C, M, and D will enable him to draw the curve.

After locating these points, draw a free-hand curve passing through them.

Second Method. Draw the two axes $A\ B$ and $P\ Q$ in the same manner as in the first method. With O as a center and a radius equal to one-half the major axis, describe a circle. Similarly with the same center and a radius equal to one-half the minor axis, describe another circle. Draw any radii such as $O\ C$, $O\ D$, $O\ E$, $O\ F$, etc., cutting both circumferences. These radii may be drawn with the 60 and 45 degree triangles. From C, D, E, and F, the points of intersection of the radii with the large circle, draw *vertical* lines and from C', D', E', and F' the points of intersection of the radii with

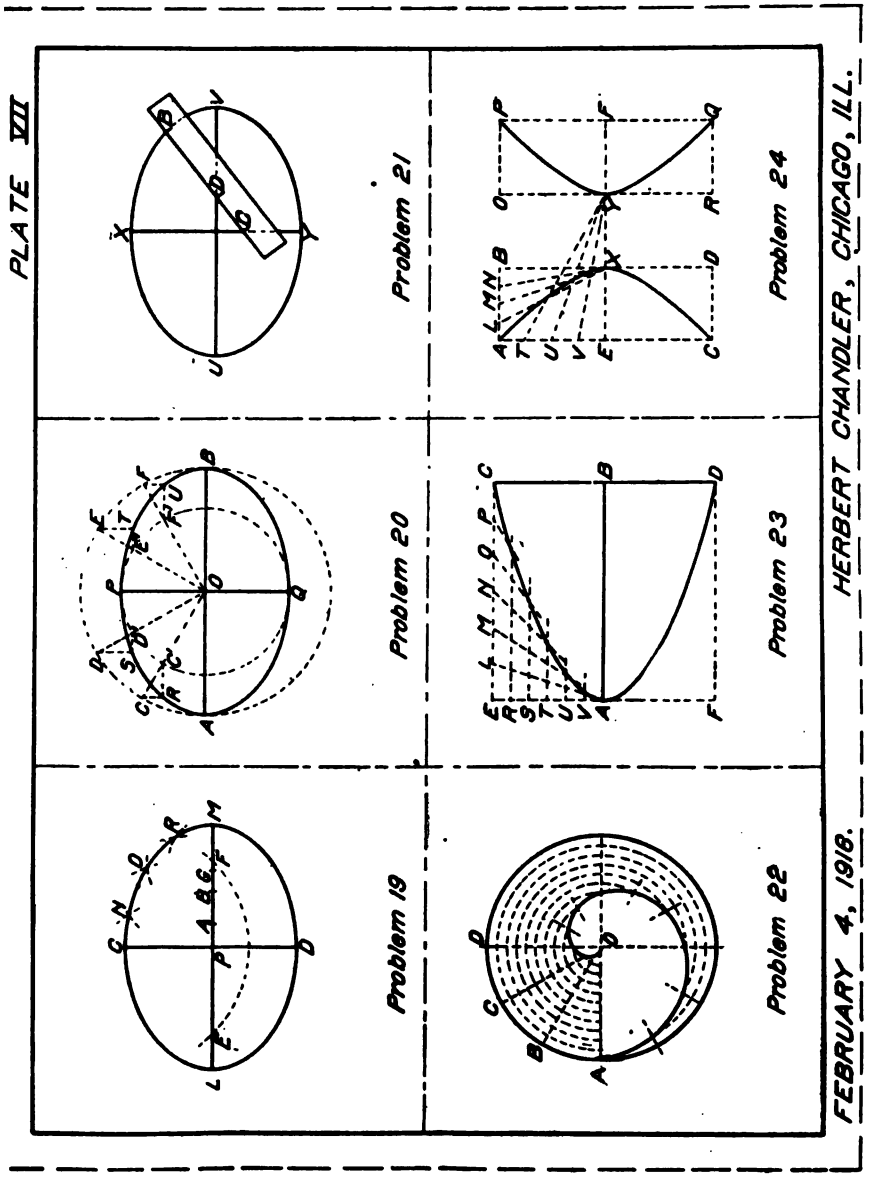


PLATE XIII
Problem 19
Problem 20
Problem 21
Problem 22
Problem 23
Problem 24
FEBRUARY 4, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

the small circle, draw *horizontal* lines The intersections of these lines are points on the ellipse.

Draw a free-hand curve* passing through these points; about five points in each quadrant will be sufficient.

Problem 21. *To draw an ellipse by means of a trammel.*

As in Problems 19 and 20, draw the major and minor axes, *U V* and *X Y*. Take a slip of paper having a straight edge and mark off *C B* equal to one-half the major axis, and *D B* equal to one-half the minor axis. Place the slip of paper in various positions keeping the point *D* on the major axis and the point *C* on the minor axis. If this is done, the point *B* will mark various points on the curve. Find as many points as necessary and sketch the ellipse.

Problem 22. *To draw a spiral of one turn in a circle.*

Draw a circle with the center at *O* and a radius of $1\frac{1}{2}$ inches. Locate twelve points, $\frac{1}{8}$ inch apart on the radius *O A* and draw circles through these points. With the 30-degree triangle, draw radii *OB, OC, OD,* etc., 30 degrees apart, thus forming 12 equal parts.

The points on the spiral are now located; the first is at the center *O;* the next is at the intersection of the line *O B* and the first circle; the third is at the intersection of *O C* and the second circle; the other points are located in the same way. Sketch in pencil a smooth curve passing through these points.

Problem 23. *To draw a parabola when the abscissa and ordinate are given.*

Draw the straight line *A B*—about three inches long—as the axis, or *abscissa* of the parabola. At *A* and *B* draw the lines *E F* and *C D* perpendicular to *A B,* and with the T-square draw *E C* and *F D,* $1\frac{1}{2}$ inches above and below *A B,* respectively. Let *A* be the vertex of the parabola. Divide *A E* and *E C* into the same number of equal parts. Through *R, S, T, U,* and *V,* draw horizontal lines and connect *L, M, N, O,* and *P,* with *A.* The intersections of the horizontal lines with the oblique lines are points on the curve. For instance, the intersection of *A L* and the line *V* is one point and the intersection of *A M* and the line *U* is another.

The lower part of the curve *A D* is drawn in a similar manner.

Problem 24. *To draw a hyperbola when the abscissa E X, the ordinate A E, and the diameter X Y are given.*

*See Page 16, Mechanical Drawing, Part I.

Draw *E F* about 3 inches long and mark the point *X*, 1 inch from *E* and the point *Y*, 1 inch from *X*. With the triangle and T-square, draw the rectangles *A B D C* and *O P Q R* such that *A B* is 1 inch in length and *A C*, 3 inches in length. Divide *A E* and *A B* into the same number of equal parts. Connect *Y* with the points *T*, *U*, and *V*, on *A E*, and connect *X* with *L*, *M*, and *N*, on *A B*. The first point on the curve is at *A;* the next is at the intersection of *T Y* and *L X;* the third is at the intersection of *U Y* and *M X*. The remaining points are found in the same manner. Repeat the process for *X C* and the right-hand curve *P Y Q*.

Inking. In inking the figures on this plate, use the French or irregular curve and make full lines for the curves and their axes. Dot the construction lines as usual. Ink in all the construction lines used in finding one-half of a curve, and in Problems 19, 20, 23, and 24 leave all construction lines in *pencil* except those inked. In Problems 21 and 22 erase all construction lines not inked. The trammel used in Problem 21 may be drawn in the position shown, or outside of the ellipse in any convenient place.

The same lettering should be done on this plate as on previous plates

PLATE VIII

Penciling. In laying out *Plate VIII*, draw the border lines and horizontal and vertical center lines as in previous plates, dividing the plate into four spaces.

Problem 25. *To construct a cycloid when the diameter of the generating circle is given.*

With *O'* as a center and a radius of $\frac{7}{8}$ inch draw a circle, and, tangent to it, draw the indefinite horizontal straight line *A B*. Divide the circle into any number of equal parts—12 for instance—and through these points of division *C*, *D*, *E*, *F*, etc., draw horizontal lines. Now with the dividers set so that the distance between the points is equal to the chord of the arc *C D*, mark off the points *L*, *M*, *N*, *O*, *P*, on the line *A B*, commencing at the point *H*. At these points erect perpendiculars to the center line *X O'* which is the line of centers of the generating circle as it rolls along the line *A B*. With the intersections *Q*, *R*, *S*, *T*, etc., as centers describe arcs of circles as shown. The points on the cycloid will be the intersections of

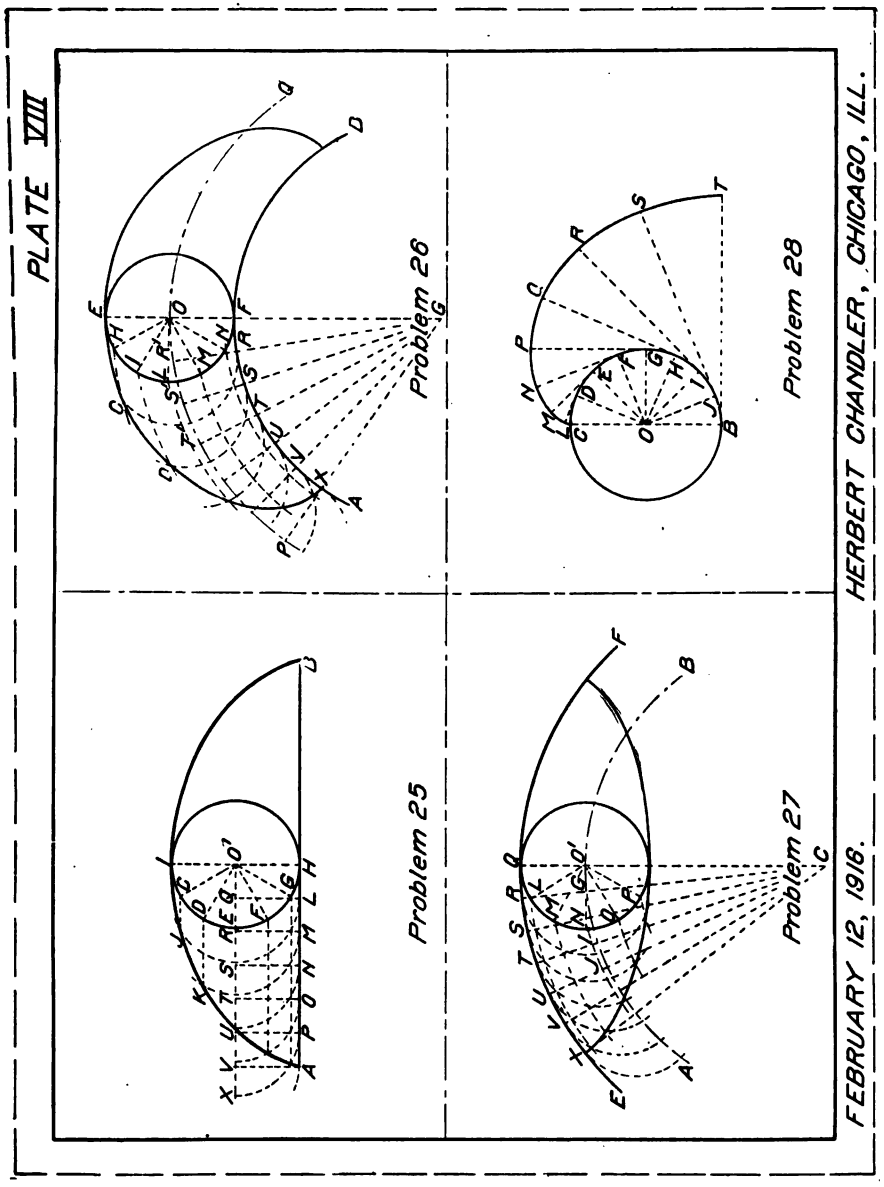


PLATE XIII
Problem 26
Problem 28
Problem 25
Problem 27
FEBRUARY 12, 1916.
HERBERT CHANDLER, CHICAGO, ILL.

these arcs and the horizontal lines drawn through the points *C*, *D*, *E*, *F*, etc. Thus the intersection of the arc whose center is *Q* and the horizontal line through *C* is a point *J* on the curve. Similarly, the intersection of the arc whose center is *R* and the horizontal line through *D* is the point *K* on the curve. The remaining points on the left, as well as those on the right, are found in the same manner. To obtain great accuracy in this curve, the circle should be divided into a large number of equal parts, because the greater the number of divisions the less the error due to the difference in length between a chord and its arc.

Problem 26. *To construct an epicycloid when the diameter of the generating circle and the diameter of the director circle are given.*

The epicycloid and the hypocycloid may be drawn in the same manner as the cycloid if arcs of circles are used in place of the horizontal lines. With *O* as a center and a radius of $\frac{3}{4}$ inch describe a circle. Draw the diameter *E F* of this circle and produce *E F* to *G* such that the line *F G* is $2\frac{3}{4}$ inches long. With *G* as a center and a radius *F G*, describe the arc *A B* of the director circle. With the same center *G*, draw the arc *P Q* which will be the path of the center of the generating circle as it rolls along the arc *A B*. Now divide the generating circle into any number of equal parts—twelve for instance—and through the points of division *H*, *I*, *L*, *M*, and *N*, draw arcs having *G* as a center. With the dividers set so that the distance between the points is equal to the chord *H I*, mark off distances on the director circle *A F B*. Through these points of division *R*, *S*, *T*, *U*, etc., draw radii intersecting the arc *P Q* in the points *R'*, *S'*, *T'*, etc., and with these points as centers describe arcs of circles as in Problem 25. The intersections of these arcs with the arcs already drawn through the points *H*, *I*, *L*, *M*, etc., are points on the epicycloid. Thus the intersection of the circle whose center is *R'* with the arc drawn through the point *H* is a point upon the curve. Also the arc whose center is *S'* with the arc drawn through the point *I* is another point on the curve. The remaining points are found by repeating this process.

Problem 27. *To draw an hypocycloid when the diameter of the generating circle and the radius of the director circle are given.*

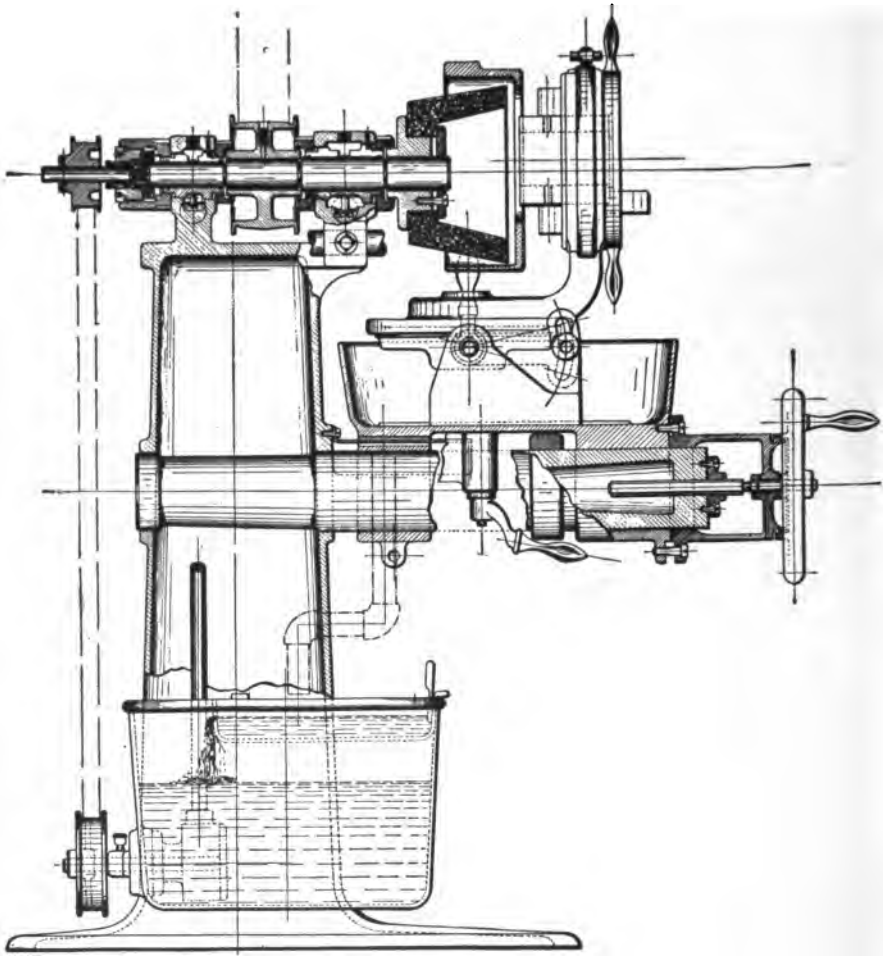
With *C* as a center and a radius of 4 inches describe the arc *E F*, which is the arc of the director circle. Now with the same

center and a radius of $3\frac{1}{4}$ inches, describe the arc A B, which is the line of centers of the generating circle as it rolls on the director circle. With O' as a center and a radius of $\frac{3}{4}$ inch describe the generating circle. As before, divide the generating circle into any number of equal parts—12, for instance—and with these points of division L, M, N, O, etc., draw arcs having C as a center. Upon the arc E F, lay off distances Q R, R S, S T, etc., equal to the chord Q L. Draw radii from the points R, S, T, etc., to the center of the director circle C and describe arcs of circles having a radius equal to the radius of the generating circle, using the points G, I, J, etc., as centers. As in Problem 26, the intersections of the arcs are the points on the hypocycloid. By repeating this process, the right-hand portion of the curve may be drawn.

Problem 28. *To draw the involute of a circle when the diameter of the base circle is known.*

With the point O as a center and a radius of 1 inch, describe the base circle. Divide the circle into any number of equal parts—16, for instance—and draw radii to the points of division. At the point D, draw a light pencil line perpendicular to O D. This line will be tangent to the circle. Similarly at the points E, F, G, H, etc., draw tangents to the circle. Set the dividers so that the distance between the points will be equal to the chord of the arc C D, and measure this distance from D along the tangent. From the point E, measure on the tangent a distance equal to two of these chords; from the point F, three divisions; and from the point G, four divisions. Similarly, measure distances on the remaining tangents, each time adding the length of the chord. This will give the points L, M, N, P, etc., to T. The curve drawn through these points will be the involute of the circle.

Inking. Observe the same rules in inking *Plate VIII* as were given for *Plate VII*. In Problems 25 and 26 the arcs and lines used in locating the points of the other half of the curve may be left in pencil. In Problem 28, all construction lines should be inked. After completing the problems the same lettering should be done on this plate as on previous plates.



GISHOLT TOOL GRINDER
Courtesy of Gisholt Machine Company, Madison, Wisconsin

MECHANICAL DRAWING

PART III

PROJECTIONS

ORTHOGRAPHIC PROJECTION

Definitions. *Projection.* The word projection means *to throw forward.* In mechanical drawing, the significance is *to throw forward in straight lines.* Projection really means, therefore, either the act or the result of projecting parallel rays from the surface of a body and of cutting these rays with a plane, so as to obtain on the

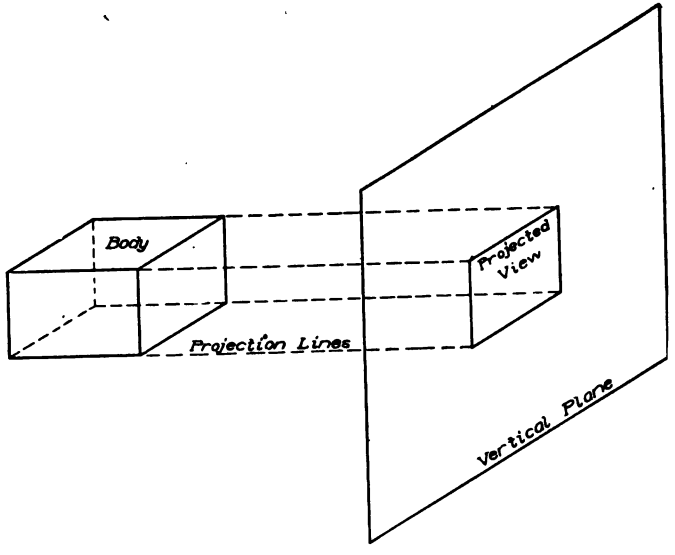


Fig. 95. Body and Its Projection

plane a shape corresponding point for point with that of the body. The rays are called *projecting lines.* A plane may be considered transparent, since it is a flat surface having no thickness.

View. In Fig. 95 a body is shown as projecting from its surface projection lines, and these lines are cut by a plane. By connecting the points on the plane made by the projection lines the

projection of the body is formed, and it corresponds in shape with the body itself. A projection of this kind is called a *view*, this name being given it on account of the fact that an observer on the same side of the body as the projection plane would get this view.

It can readily be seen that one view only will not give a complete picture of a solid object. Usually two or more views are necessary, according to the complication of the object or body. When two or three views are shown, they are pictured on two or three planes at right angles to each other. In this way views of two or three sides are shown, and this is usually sufficient to give the idea of the complete form of the object.

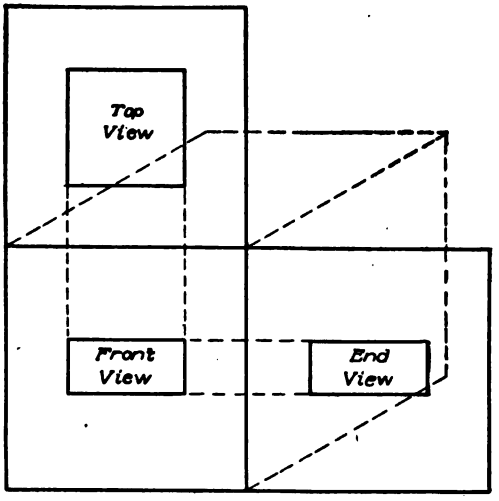


Fig. 96. Projections of Top, Front, and End of Body

Orthographic. The word *orthographic* means at right angles, and in mechanical drawing, in connection with the word projection, it means that two or more views are projected on planes at right angles with each other. The various views of a body have special names—those showing vertical faces are called *elevations*, such as front, side, end or rear elevation; a view of the top of a body is called a *plan* or *plan view;* and a view of the under side, a *bottom view.*

Third-Angle Projection. In Fig. 96 is shown three faces of a body projected on three planes—the top view on the top plane, the front view on the front plane, and the end view on the end plane. It will be seen that the same body is represented as projecting rays in three directions, and thus the three projections, or views, are obtained. It will also be seen that the three planes with their views have been brought into one plane, that is, the surface of the paper. This brings the top view directly above the front view, and the end view to the right of the front view. The above is a definition of

true projection, usually called *third-angle projection*, and is the method used by practically all draftsmen in this country.

First-Angle Projection. There is, however, a method called first-angle projection, used but little now in this country, although formerly in almost general use. Because draftsmen may have to do at times with old drawings or drawings made in foreign countries, it is well for them to understand first-angle projection. This method

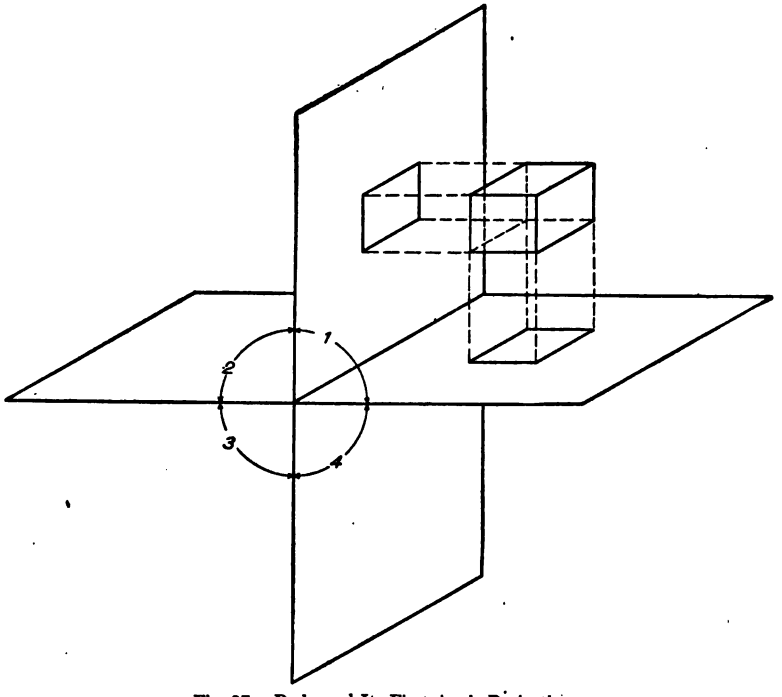


Fig. 97. Body and Its First-Angle Projections

brings the front view, or elevation, above the top view, or plan, the end view being at the right of the front view. Fig. 97 shows this method of first-angle projection.

Comparison of Third- and First-Angle Projection. Perhaps a short explanation will make clear the meaning of third- and first-angle projection. In geometry, when two planes intersect at right angles, the angles are designated as first, second, third, and fourth, as numbered in Fig. 97. In first-angle projection, the body is placed in angle 1, and a top view is projected on a plane under the body.

This passes the projection lines back through the body, instead of throwing them out from the surface. In fact, by this method, the body is supposed to turn itself inside out, an absurdity which led to the general abandonment of the method in this country. Third-angle projection places a body in angle 3, and projects a top view on to the plane above it, and a front view on to the plane in front of it. This is true projection.

Projection Methods. When a drawing is made by projection, an object is represented just as it would be seen if one eye were closed and the other were directly over each point of the object at the same time. As an illustration of this, place a box on a table and a piece of ground glass a few inches in front of it. Now, stand

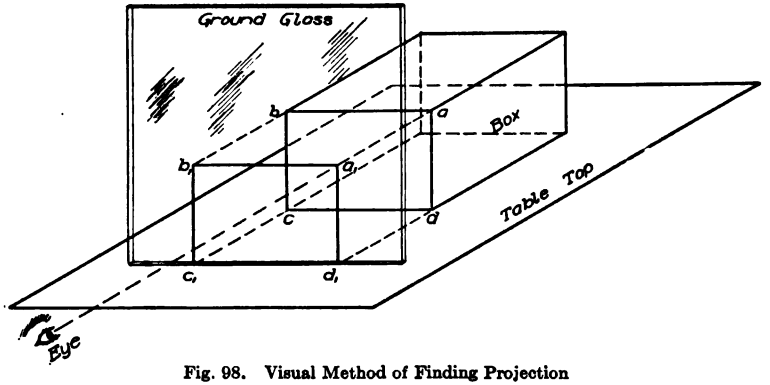


Fig. 98. Visual Method of Finding Projection

so that one eye will come directly in line with one corner a, Fig. 98. Make a dot at a_1 where the line from the eye to the corner a passes through the glass. Next, move the eye until it is directly in line with the corner b of the box, and put a dot at b_1 where the line from the eye to the corner b passes through the glass. Repeat this process, putting dots on the glass at c_1 and d_1 where the lines from the eye to the corners c and d pass through the glass. Now, connect the points a_1, b_1, c_1, and d_1, and the complete projection of the front of the box will be shown by the figure on the glass. This

NOTE. The first four figures in this textbook, Figs. 95, 96, 97, and 98, are pictorial views given to show the student clearly how the views of objects are projected. The student in drawing orthographic projections does not need to draw the pictorial views, but simply the projections, as illustrated in Figs. 99 to 129, inclusive.

figure is a rectangle, and is the same shape and size as the front of the box.

It is readily seen that from this one projection drawing, or view, no idea of the depth of the box is given, although the width and height are correctly shown. A top, or plan, view must now be made to show the depth of the box. Place another piece of ground glass a few inches above the box and, with the eye directly over each separate corner of the top, repeat the process of making the four dots, representing each top corner. Connect these four dots, and the figure thus formed represents the top projection, or plan view, of the box. Now, arrange the two pieces of glass, as shown in Fig. 99. The box being removed, the upper glass is simply lowered to the table, and the front glass is turned from the bottom forward and up, and laid directly below the upper glass.

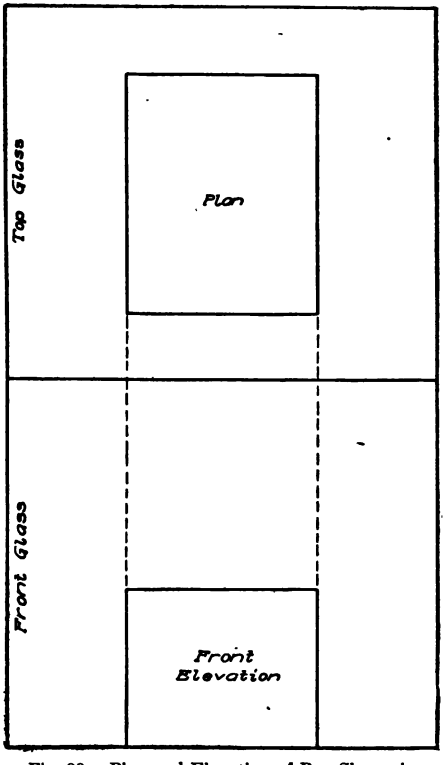


Fig. 99. Plan and Elevation of Box Shown in Fig. 98

This position of the figures represents the two projections—front elevation and plan—just as they would be drawn by a draftsman on a sheet of drawing paper. The width of the box is shown in both views, and being the same in each, the front elevation and plan are both of equal width, and therefore each point in the plan is directly over the corresponding point in the front elevation. In more complicated objects, where the complete idea cannot be obtained from the front elevation and plan views, an end view or both end views must be shown as in Fig. 100, which represents the projections of a box with a curved top. These end views are obtained by taking two or more

pieces of ground glass, placing them one in front of each end, and then drawing the projections. This is done, as in the cases of the

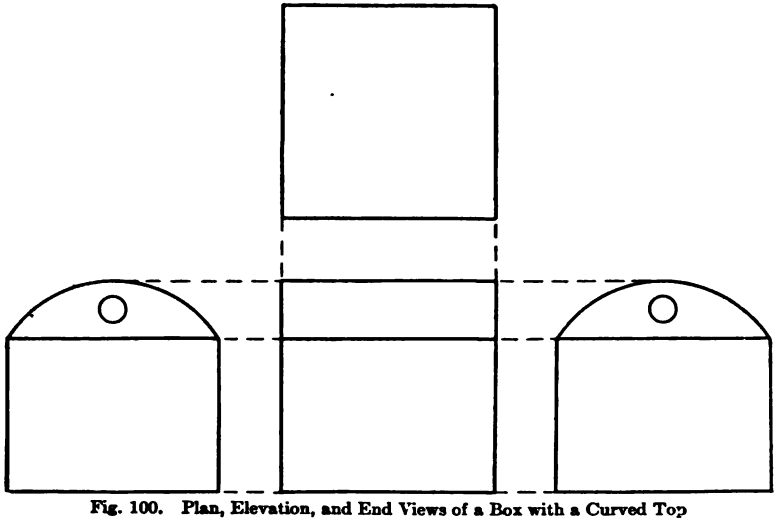


Fig. 100. Plan, Elevation, and End Views of a Box with a Curved Top

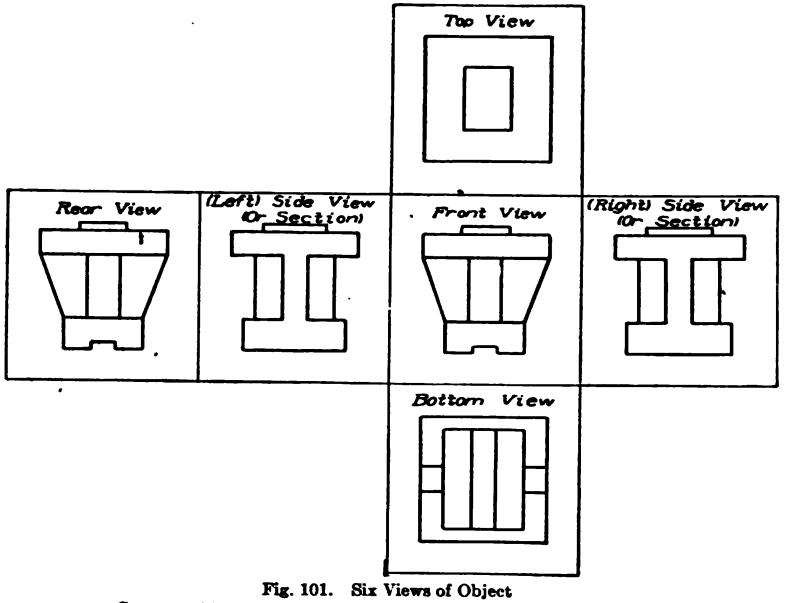


Fig. 101. Six Views of Object
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

front elevation and plan, by making several dots for the shape of the top, and drawing a curved line through these dots. The two

end views are placed as shown—the right-hand view at the right of the front view, and the left-hand view at the left. This gives the proper arrangement of the views as a draftsman would work them out on paper.

In Fig. 101 is represented a practical case where the object is sufficiently complicated to require a view of each of its six faces. As will be seen in the figure, six views are shown—front, top,

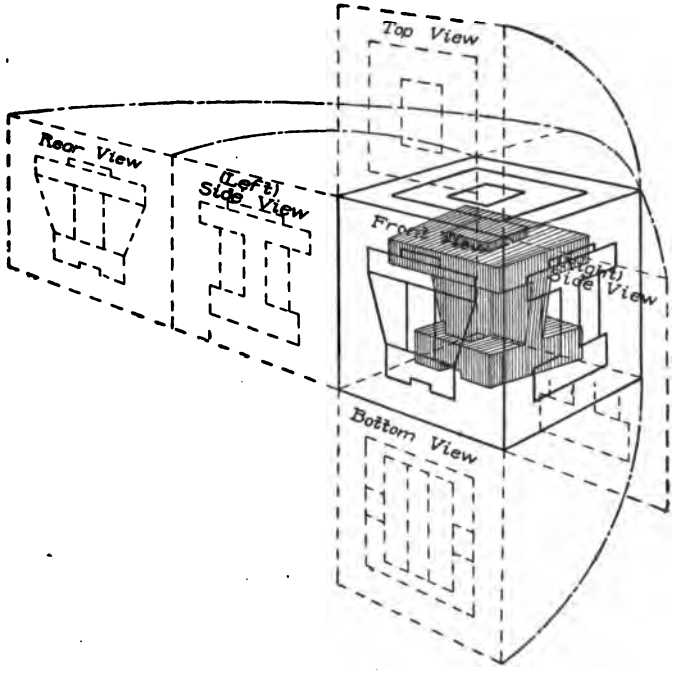


Fig. 102. Folding Out of the Projection Planes Into the Plane of the Surface of the Drawing Paper
Courtesy of Pennsylvania Railroad Company, Altoona, Pennsylvania

bottom, right side, left side, and rear. In Fig. 102 is represented the method of folding out the projection planes after the faces of the object have been projected on them, in order to have them all in one plane—that of the surface of the drawing paper, as shown in Fig. 101.

Drawing the Projection on Paper. From the explanation just given, it will be seen that the projection views are all of the same size as the faces of the object they represent. They can, therefore,

be drawn just as readily on a sheet of drawing paper without the use of the ground glass. For the front view, measure the four front edges of the object, and lay off on the paper a figure of the same shape as the front of the object. Repeat the process for the top of the object, obtaining the top view, or plan; and for each end of the object, obtaining the end view, or side views. The bottom and rear views can be placed in the same way. Draw the plan view with its four corners directly over the four corners of the front view, and the bottom view with its four corners directly under. Draw the right end, or side, view with its four corners directly to the right of the four corners of the front elevation, and the left end, or left side, view and rear view, with their corners directly to the left of the corners of the front view.

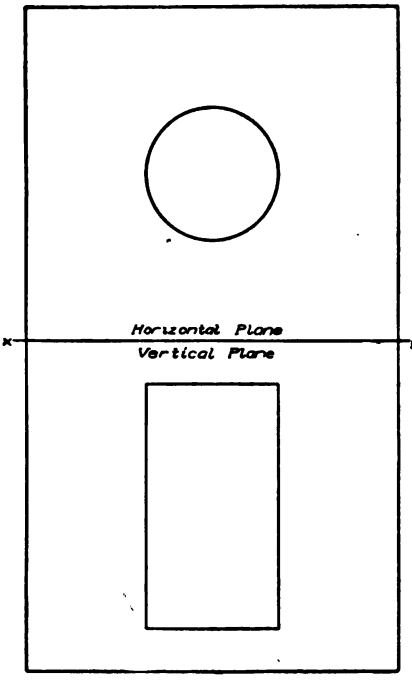


Fig. 103. Ground Line, xy, at Intersection of Horizontal and Vertical Planes

Projection Lines. As each projected point of an object shown in plan view must be directly over the projection of the same point in the front elevation, a vertical dotted line will connect these points, as projected in pairs; and as each projected point in an end view must be directly opposite the projection of the same point in the front elevation, a horizontal dotted line will connect these points, as projected in pairs. These dotted lines are called projection or construction lines.

Ground Line. Having the two planes, at right angles, on which the front elevation and plan are represented, when the top plane is turned up to bring the plan above the front elevation, as represented on the surface of the drawing paper, it revolves on the intersecting line of the two planes as an axis. This intersecting line xy

in Fig. 103, is called the ground line, and this is usually abbreviated to *GL*. The projections may be placed at any convenient distance above or below the *GL*, unless these distances are given in any problem. In beginning all ordinary projection work, it is customary to show the *GL* as a horizontal line between the front elevation and plan views, and the projection of any pair of points in the front and plan views are always in a line perpendicular to the *GL*. This is evident from the fact that the points in the plan view are directly

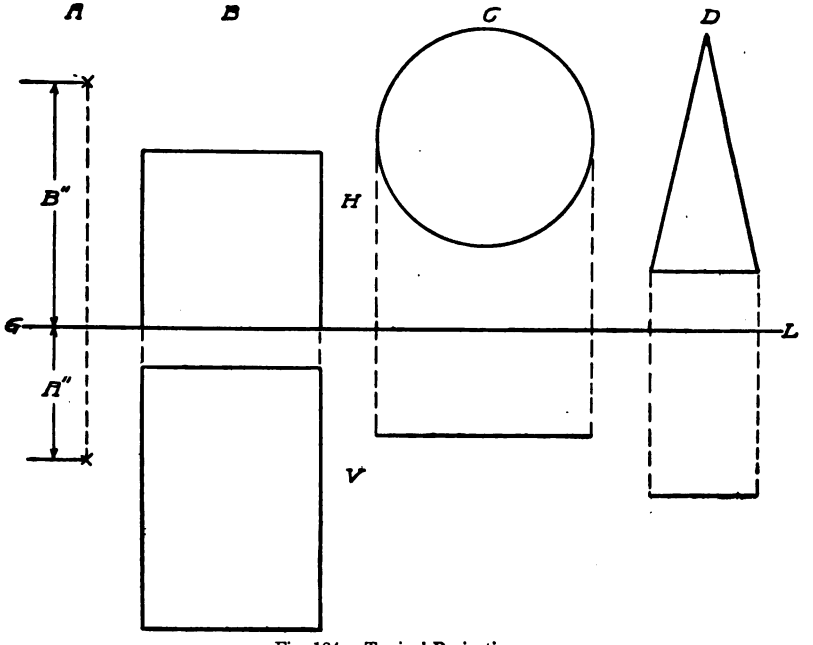


Fig. 104. Typical Projections

over the corresponding points in the front elevation. Although the ground line is usually used in learning the subject of projections, it is customary to omit it in practical work.

Rules of Projection. (1) *If a surface is perpendicular to either plane of projection, its projection on that plane is simply a line—a straight line if the surface is plane, a curved line if the surface is curved.*

(2) *The projected view of any point of any object on a plane is in a perpendicular drawn to the plane through the point of the object.*

(3) *If a straight line is perpendicular to a plane, its projection on that plane is a point; and if the straight line is parallel to the plane, the projection is a line equal in length to the line itself and makes the same angle with the ground line.*

(4) *All points on any object at the same height above its base must appear in the front elevation at the same distance below the ground line, and all points on an object at the same distance back of the front face must appear in the plan at the same distance above the ground line.*

Typical Examples of Projection. Figs. 104 and 105 show clearly several ideas of plan and elevation. In such work as this, it is

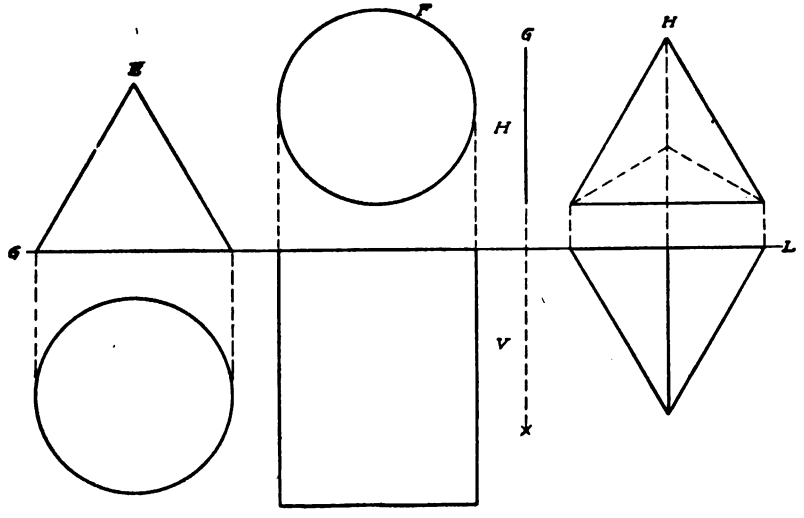


Fig. 105. Typical Projections

customary to call the vertical plane on which the front elevation is drawn V, and the horizontal plane on which the plan is drawn H.

A = a point A'' below H, and B'' in front of V

B = a square prism resting against V, two of its faces parallel to H

C = a circular disk in space parallel to H

D = a triangular card in space parallel to H

E = a cone with its base resting against V

F = a cylinder perpendicular to H, and with one end resting against H

G = a line perpendicular to V

H = a triangular pyramid back of V, with its base resting against H

PRACTICAL PROBLEMS IN PROJECTION

1. *Square Bar.* Fig. 106 represents a square bar. A is the front elevation, and shows the length and width of the bar, but not the thickness. There must then be another view. B is the plan,

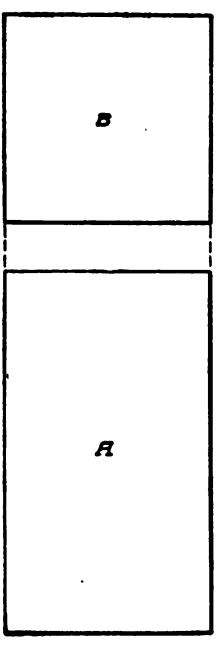


Fig. 106. Projections of Square Bar

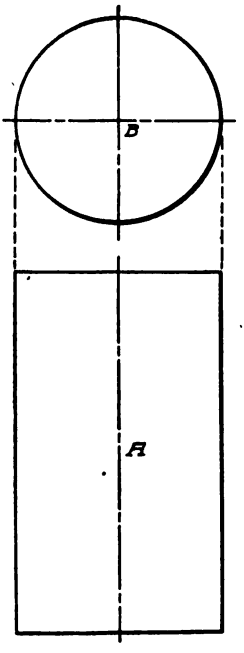


Fig. 107. Projections of Round Bar

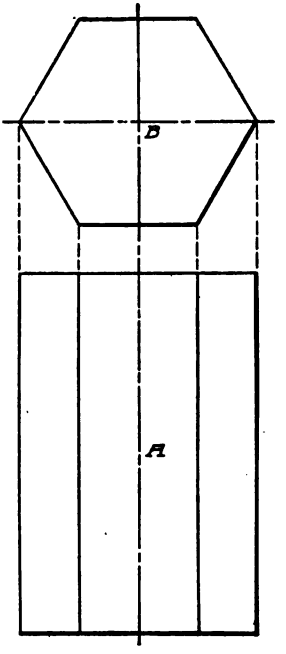


Fig. 108. Projections of Hexagonal Bar

and shows the width and thickness of the bar. From these two views the complete form of the bar is obtained and no other views are necessary when such is the case. In all working drawings, only as many views are shown as is necessary to determine the complete form of the object being drawn.

2. *Round Bar.* Fig. 107 represents a round bar. The front elevation A, shows the width and height of the bar, but does not show that it is round. The plan B, shows the circular top of the bar and of the proper diameter. In this problem, in addition to the

dotted projection lines connecting points in plan and elevation, it is advisable to put in dot and dash lines for center lines. Projection lines and center lines are construction lines, and may be erased when the drawing is finished, unless otherwise ordered.

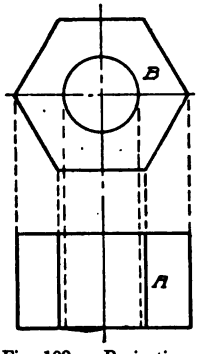


Fig. 109. Projections of Hexagonal Nut

3. *Hexagonal Bar.* Fig. 108 represents a hexagonal bar. In this case, center lines should be drawn. The front elevation *A*, shows the length of the bar, and the plan *B*, shows the form and the distance between faces. The vertical lines in the front elevation show the corners of the hexagonal form while both views show the distance from corner to corner of the hexagonal top.

4. *Hexagonal Nut.* Fig. 109 represents a hexagonal nut. Center lines should be drawn here also. The front elevation *A*, shows the thickness and width of the nut, and the circular hole is shown by heavy dotted lines. Holes are always represented in this way. The plan *B*, shows the shape of the top of the nut, and also the shape of the hole.

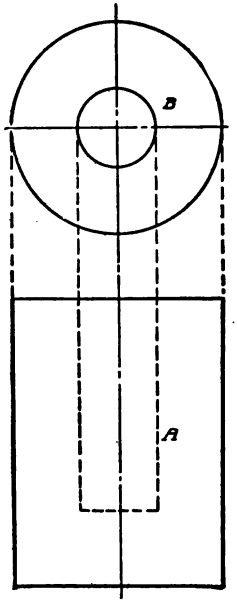


Fig. 110. Projections of Cylinder with Circular Hole

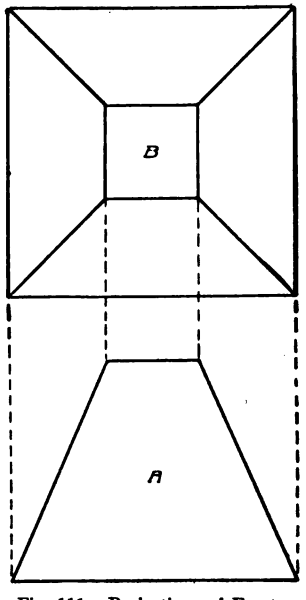


Fig. 111. Projections of Frustum of Square Pyramid

5. *Cylinder with Circular Hole.* Fig. 110 represents a cylinder with a circular hole passing part way through. Center lines are needed here, and in fact where any circle, hexagon, octagon, or other shape except a square or rectangle occurs. The front elevation *A*, shows the height and width of the cylinder, and the depth and width of hole. The plan *B*, shows the top of the cylinder, its diameter, and the diameter of the hole.

6. *Frustum of Square Pyramid.* Fig. 111 represents a block in the form of a frustum of a square pyramid. The front elevation *A*, shows the height of the block, and the width of the top and bottom faces. The plan *B*, shows the width and depth of the top and bottom faces, and also the edges connecting these faces of the frustum.

7. *Square Bar with Cylindrical Portion.* Fig. 112 represents a square bar with a portion forged to a cylindrical form. The front elevation *A*, shows the length and width of the bar, and also the length and width of the cylindrical portion. The plan *B*, shows the square top, and by the dotted circle shows the shape of the cylindrical portion. The fact that this circle is dotted means that the cylindrical portion does not come clear through to the top. A bottom view *C*, is also shown here, as it gives a better idea of the complete form of the bar. Enough views should always be shown by the draftsman to give the workman a clear idea of what he is to make.

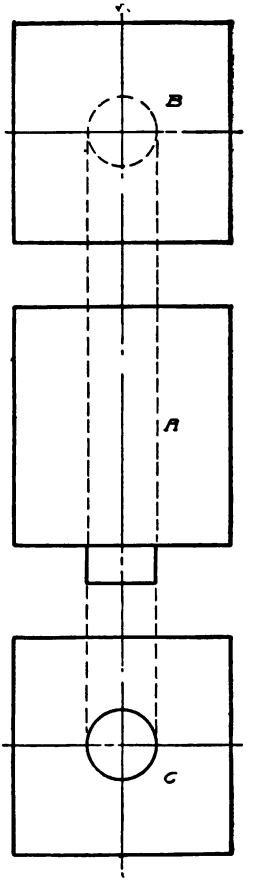


Fig. 112. Projections of Square Bar with Cylindrical Portion

8. *Circular Ring Made from Round Rod.* Fig. 113 represents a circular ring made from a round rod. The front elevation *A*, shows the thickness and the diameter of the ring, and the plan *B*, shows the circular form.

9. *Block with Number of Different Dimensions.* Fig. 114 represents a block with a number of different dimensions. The block

has been turned down in such a way that there are five different diameters, as shown. All these diameters, and the lengths between, may be shown in the front elevation *A*. From this view, only the forms of the cross-section could not be ascertained. Some might be square, some hexagonal, or some circular, but the plan *B* shows that all are circular.

Summary. The principles of projection which have been used so far, may be stated as follows:

(1) If a line is parallel to either the vertical or horizontal plane, its actual length is shown on that plane, and its other projection is parallel to the ground line.

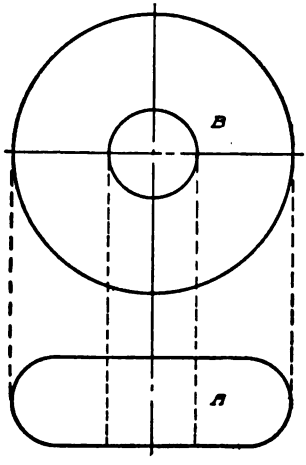


Fig. 113. Projections of Circular Ring

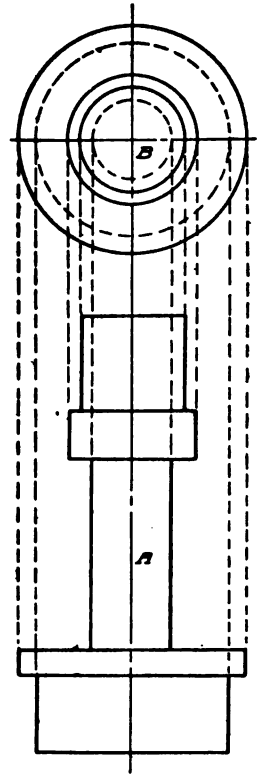


Fig. 114. Projections of Turned Block

(2) A line oblique to either plane has its projections on that plane shorter than the line itself, and its other projection oblique to the ground line.

(3) No projection can be longer than the line itself.

(4) If two lines intersect, their projections must cross, and the point of crossing in the front elevation must be directly under the point of crossing in the plan.

(5) A plane surface, if parallel to either plane, is shown on that plane in its true size and shape; if oblique, it is shown smaller than the true size, and if perpendicular it is shown as a straight line.

(6) Lines parallel in space have both their vertical and horizontal projections parallel.

TRUE LENGTH OF LINES

Principles. If a line is parallel to a plane, its projection on that plane will be equal in length to the line itself, as represented in Fig. 115. If a line is perpendicular to a plane, its projection on the plane will be a point, as represented by the cross in Fig. 116. If a line is inclined to a plane, its projection on that plane will be shorter than the line itself, as represented in Fig. 117. If a line is parallel to the horizontal or vertical plane, its projection on the other plane will be parallel to the ground line, as represented in Fig. 118. A line inclined to both the horizontal and vertical planes will not show its true length in either projection, as represented in Fig. 119. In a case like the one last mentioned, the true length of the line is found by revolving the line until it is parallel to one of the planes. Then, its projection on that plane will be its true length.

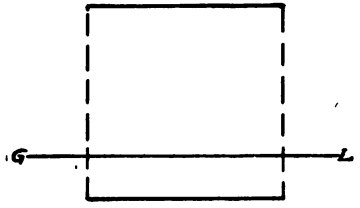


Fig. 115. Projections of a Line Parallel to Plane

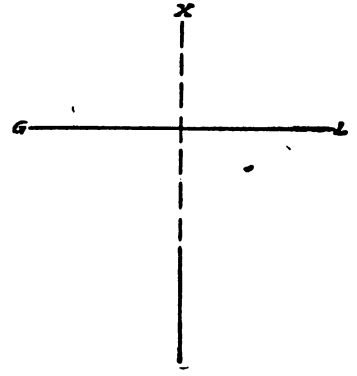


Fig. 116. Projections of a Line Perpendicular to Plane

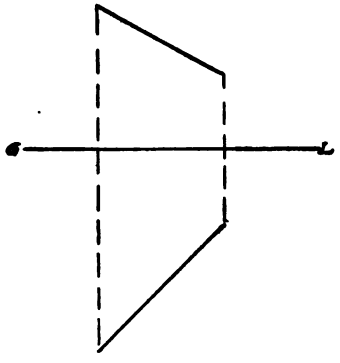


Fig. 117. Projections of a Line Inclined to Plane

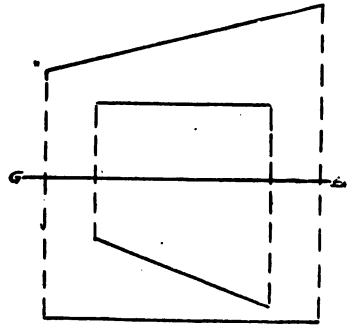


Fig. 118. Projections of Lines Parallel to Ground Line

True Length by Revolving Horizontal Projection. In Fig. 120 is shown the horizontal and vertical projections of the line AB, and to find the true length of the line itself proceed as follows: Swing the horizontal projection A^hB^h about one end A^h as a pivot, until it is parallel to the ground line. Project the new point $B_1{}^h$ downward to a point on the vertical plane to a line drawn from B^v parallel to the ground line, locating the point $B_1{}^v$. The line connecting $B_1{}^v$ and A^v is the true length desired, since the true length of a line is always shown by its projection on a plane when the line is parallel to that plane.

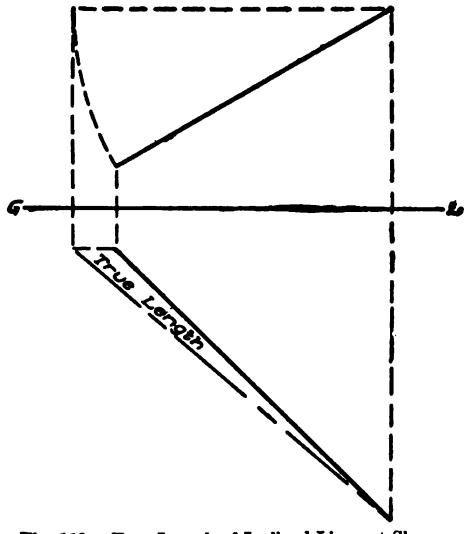


Fig. 119. True Length of Inclined Line not Shown in Its Projections

True Length by Revolving Vertical Projection. In Fig. 121 is shown the method of finding the true length of the same line as

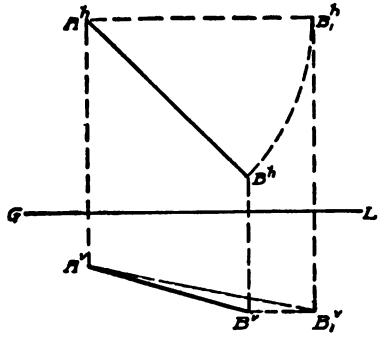


Fig. 120. True Length of a Line by Revolving Horizontal Projection

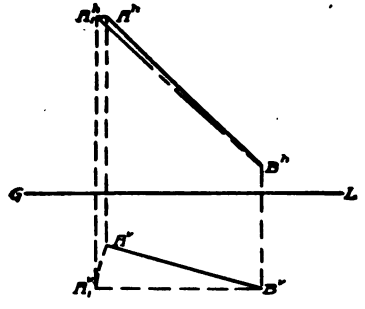


Fig. 121. True Length of a Line by Revolving Vertical Projection

in Fig. 120, but by revolving the vertical projection. The method is the same. Revolve A^vB^v about the end B^v as a pivot until it is parallel to the ground line, and then project $A_1{}^v$ up to $A_1{}^h$ on the

horizontal plane at the same distance from the ground line as A^h. The true length is then shown on the horizontal plane by the line connecting $A_1{}^h$ and B^h. Projection lines representing the true length are always shown as dot and dash lines, as in Fig. 120 and 121.

REPRESENTATION OF OBJECTS

Rectangular Prism or Block. In Fig. 122 there is represented a rectangular prism or block, whose length is twice its width. The elevation shows its height. As the block is placed at an angle, three of the vertical edges will be visible, and the fourth, invisible. In mechanical drawing, the edges, which in projection form a part of the outline or contour of the figure, must always be visible, hence are always drawn as full lines, while the lines or edges which are invisible are drawn dotted. The plan shows what lines are visible in elevation, and the elevation determines what are visible in plan. In Fig. 122, the plan shows that the dotted edge AB is the back edge, and in Fig. 123, the elevation shows that the dotted edge CD is the lower edge of the triangular prism. In general, if in elevation an edge projected *within* the figure is a back edge, it must be dotted, and in plan, if an edge projected within the outline is a lower edge, it is dotted.

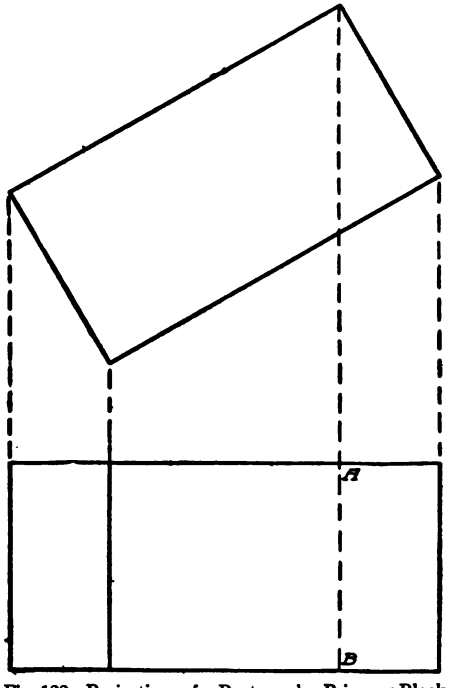


Fig. 122. Projections of a Rectangular Prism or Block

Triangular Prism or Block. The end view shown in Fig. 123 is obtained by projecting the points of the plan across to a plane at right angles to the horizontal and vertical planes, then revolving them down through 90 degrees and continuing the projections to meet the projection lines drawn across from

the elevation. Connecting the points thus obtained gives the end view. End or side views of any object are obtained by projection in this way.

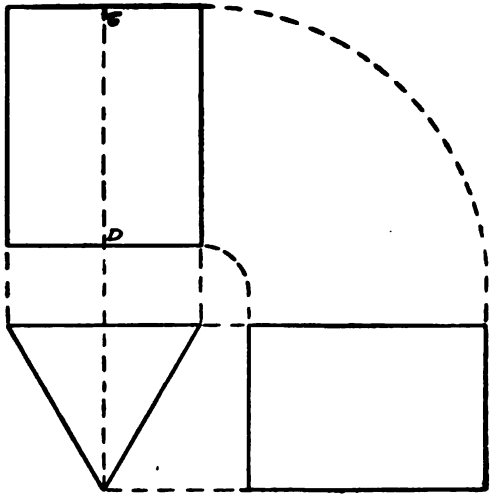


Fig. 123. Projections of a Triangular Prism or Block

Triangular Block with Square Hole. The plan, elevation, and end views of a triangular block with a square hole from end to end are shown in Fig. 124. In this case the plan and elevation alone would not be sufficient to positively determine the shape of the hole, but the end view shows at a glance that it is square.

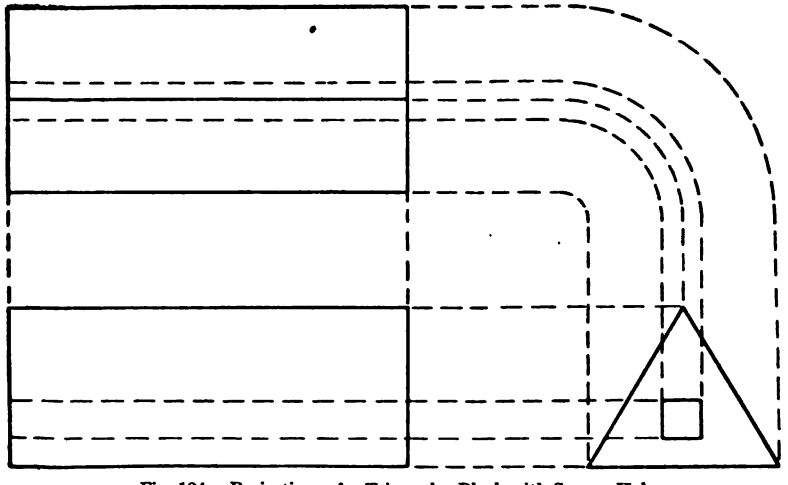


Fig. 124. Projections of a Triangular Block with Square Hole

ROTATING AND INCLINING OF OBJECTS

Method of Rotating Object. The natural way to place an object to be shown by projections would be in the simplest position; that is, with an edge or face parallel to either the horizontal or

vertical plane of projection. Sometimes it is necessary, however, to draw the views of an object in a position at an angle to the planes. In such case it is usually advisable to draw the object parallel to one of the planes, and then rotate it to the required position about an axis perpendicular to a plane of projection.

When an object is rotated in this way, about an axis perpendicular to a plane, its projection on that plane will remain unchanged

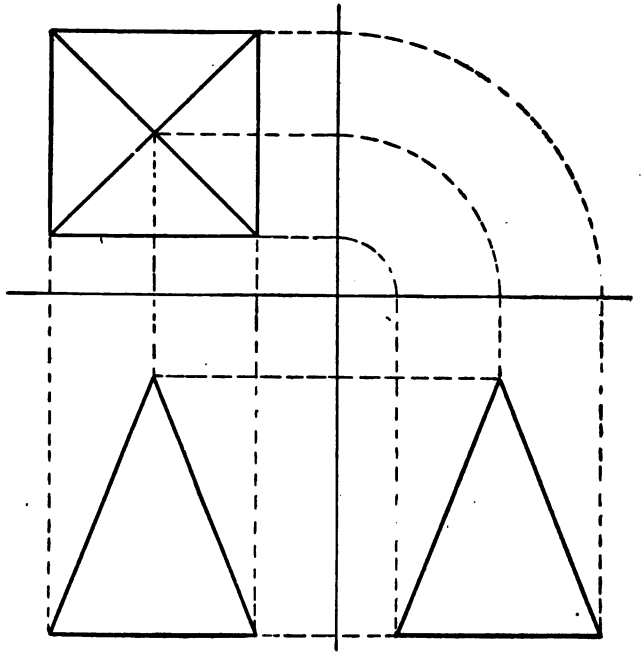


Fig. 125. Plan, Front, and Side Views of a Square Pyramid

in size and shape, and the dimensions parallel to this axis on the other planes will remain the same.

Pyramid. In Fig. 125, the plan, front, and side views of a pyramid are shown, and in Fig. 126 is shown the same pyramid after it has been rotated through 30 degrees about an axis perpendicular to the horizontal plane. The height of the pyramid has not been altered by this rotation and, therefore, the front and side views are the same height as in the original front view.

Now, if the pyramid in Fig. 125 is rotated about an axis perpendicular to the vertical plane, the front view will not be altered,

and may be copied in the new position at an angle of 30 degrees, as shown in Fig. 127. The distances above the ground line to any points in the top view are not altered, and the distances of the various points can be taken on the lines projected up from the points of the front view with a pair of dividers, or the points can be obtained by projecting across from the original top view to meet the projection lines drawn up from the front view. The side view dimensions are not altered, and this view can therefore be obtained in

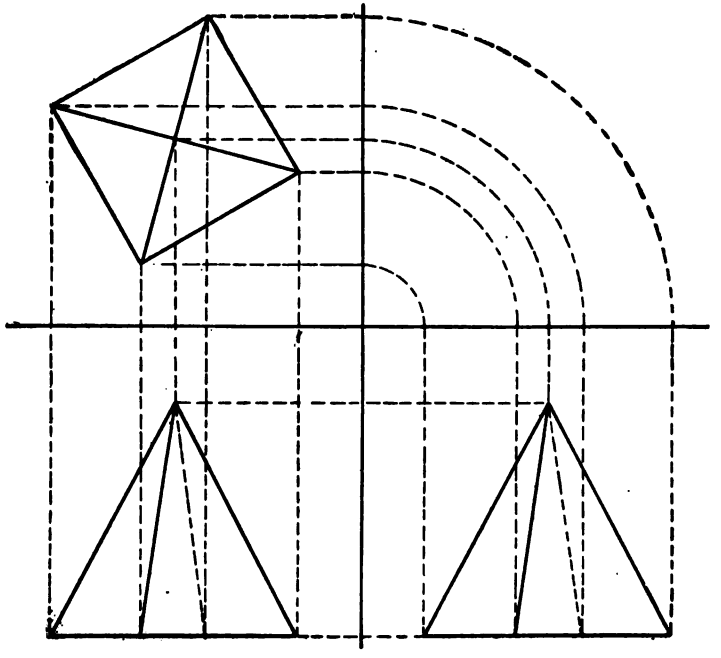


Fig. 126. Plan, Front and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Vertical Plane

the usual way, by projecting across from the front view, and revolving down from the plane at right angles to the horizontal and vertical planes the points projected across from the top view.

Cylinder in Inclined Position to Horizontal Plane. As shown in Fig. 128, first draw the plan, a circle, at *A*. Then draw the rectangle at *B*, representing the front view. Now, draw the rectangle at *C*, representing the front view at the desired angle. This rectangle *C* is the same size as the view at *B*, since the cylinder

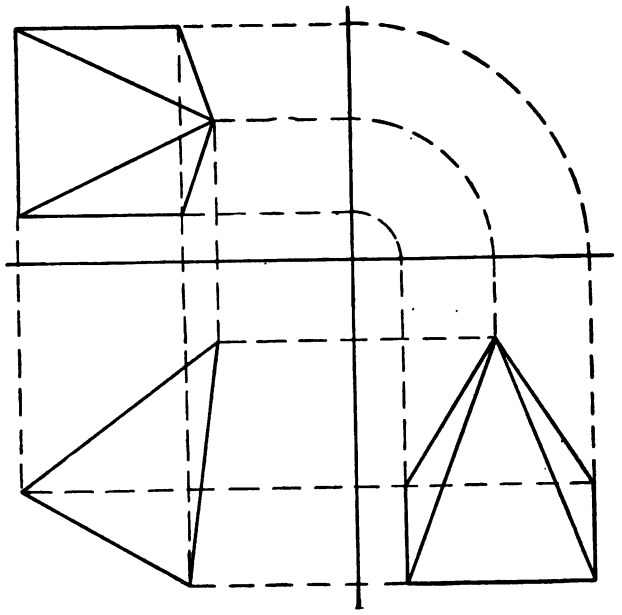


Fig. 127. Plan, Front, and Side Views after Revolving Pyramid in Fig. 125 through 30 Degrees with Horizontal Plane

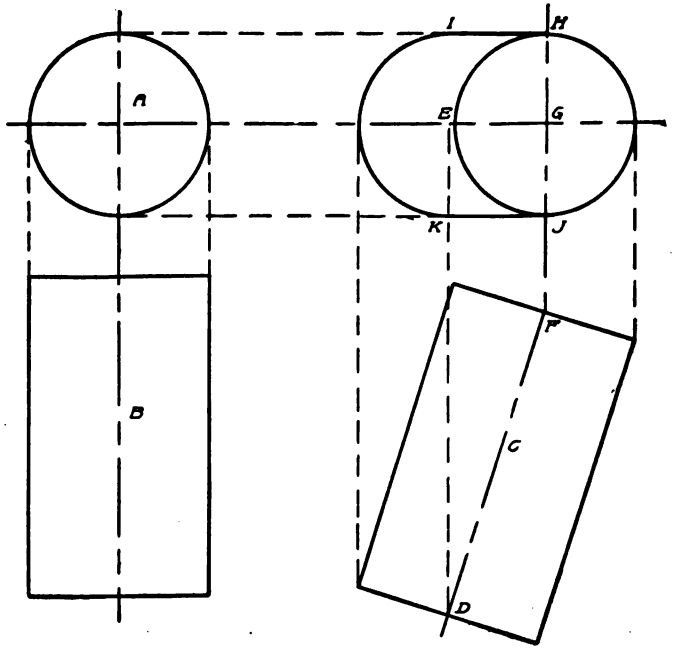


Fig. 128. Projections of Cylinder Inclined to Horizontal Plane

has simply been inclined to the horizontal plane, but kept parallel to the vertical plane. The point *D*, the center of the circle forming the base of the cylinder, is projected up to the point *E*, and with this point as a center, a circle representing the plan view of the base is drawn. Then from *F* project up to *G*, and with this point as a center draw the circle representing the plan view of the top of the

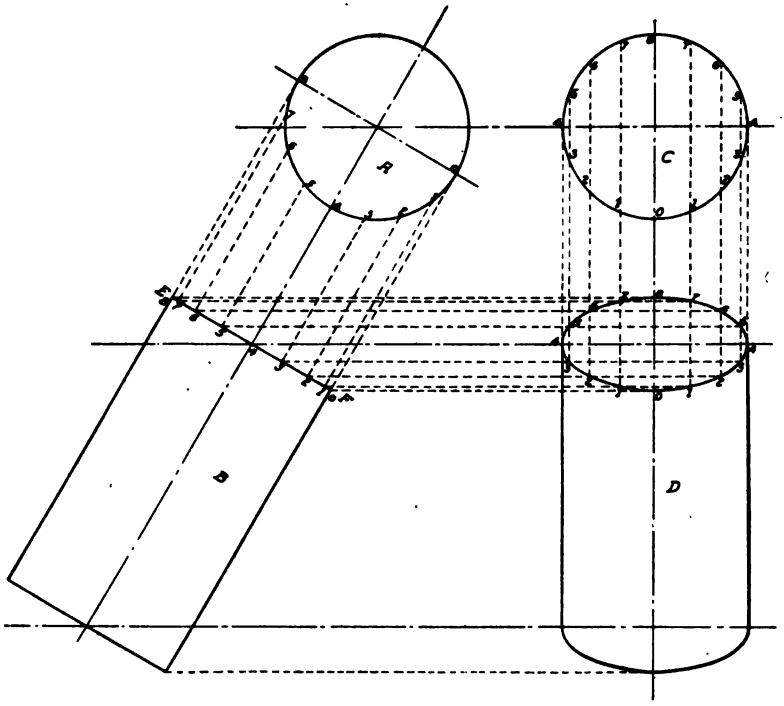


Fig. 129. Method of Finding the Projection, in the Form of an Ellipse, of the Top of a Cylinder Greatly Inclined to a Plane

cylinder. Connecting these two circles with horizontal lines *HI* and *JK*, representing the sides of the cylinder, completes the plan view, and the problem is finished.

As the cylinder is at an angle with the horizontal plane, it will be seen that the top and bottom of the cylinder in the plan view are not circles, but ellipses. It is, however, customary to draw them with the compass, as circles, when the angle of the cylinder with the plane is not great.

Cylinder Greatly Inclined to Horizontal Plane. In Fig. 129 the plan and front elevation of the top of the cylinder are drawn at the desired angle with the horizontal plane at A and B, respectively. The plan view at A is then transferred to C. In each of these plan views divide the lower semicircle into a number of equal parts, eight in this case. From the view of A, project the points 0—8, parallel to the center line, down to EF, and then project across to the projection lines drawn vertically down from the points 0—8 in C. The points of intersection of projection lines, correspondingly numbered, form the shape of the ellipse representing the top of the side view of the inclined cylinder D, and the ellipse drawn through these points completes this view. The side lines of the cylinder may now be drawn, and the curve representing the bottom of the side view may easily be copied from the lower half of the ellipse representing the top view. When the points have been located, the ellipses may be drawn through them with the aid of an irregular curve.

ILLUSTRATIVE EXAMPLES

1. *Construct plan and elevation of a regular hexagonal pyramid.* It is evident that two distinct geometrical views are necessary to convey a complete idea of the form of the object; an elevation to represent the sides of the body, and to express its height; and a plan of the upper surface to express the form horizontally.

It is to be observed that this body has an imaginary axis or center line, about which the same parts or segments of the body are equally distant; this is an essential characteristic of all symmetrical figures.

Draw a horizontal dotted line MN for the center line of the plan views, Fig. 130. Then draw a perpendicular ZZ' to MN.

In delineating the pyramid, it is necessary, in the first place, to construct the plan. The point S', where the line ZZ' intersects the line MN, is to be taken as the center of the figure, and from this point, with a radius equal to the side of the hexagon which forms the base of the pyramid, describe a circle, cutting MN in A' and D'. From these points, with the same radius, draw four arcs of circles, cutting the primary circle in four points. These six points being joined by straight lines, will form the figure $A'B'C'D'E'F'$,

which is the base of the pyramid; and the lines $A'D'$, $B'E'$, and $C'F'$, will represent the projections of its edges foreshortened as they would appear in the plan. If this operation has been correctly performed, the opposite sides of the hexagon should be parallel to each other and to one of the diagonals; this should be tested by the application of the square or other instrument proper for the purpose.

By the help of the plan obtained as above described, the vertical

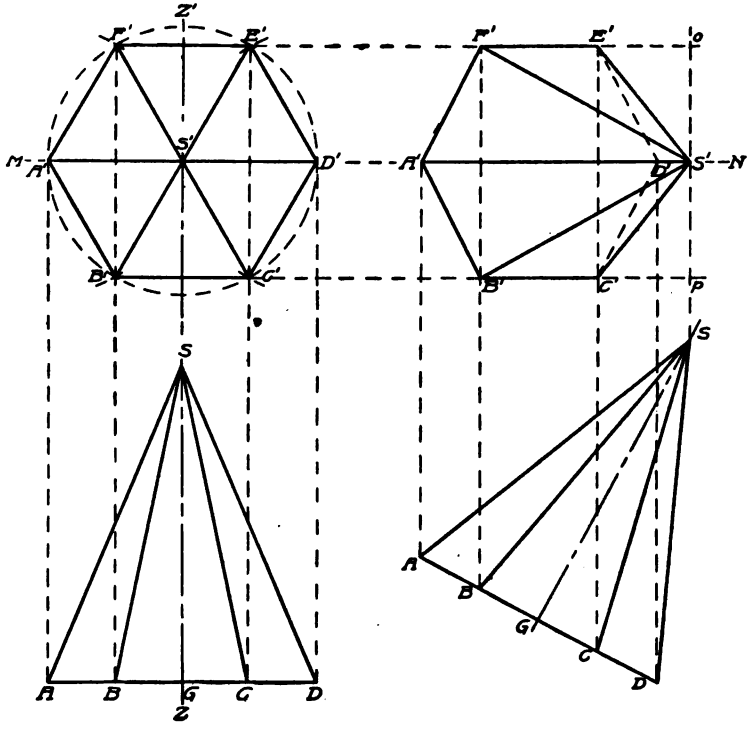


Fig. 130. Construction of Regular Hexagonal Pyramid

projection of the pyramid may be easily constructed. Since it is directly under the plan, it must be projected vertically downward; therefore, from each of points A', B', C', D', drop perpendiculars to AD, the base line of the pyramid in the elevation. The points of intersection, A, B, C, and D, are the true positions of all the angles of the base; and it only remains to determine the height of the pyramid, which is to be set off from the point G to S, and to

draw SA, SB, SC, and SD, which are the only edges of the pyramid visible in the elevation. Of these it is to be remarked that SA and SD alone, being parallel to the vertical plane, are seen in their true length; and, moreover, that from the assumed position of the solid under examination, the points F' and E' being situated in the lines BB' and CC', the lines SB and SC are each the projections of two edges of the pyramid.

2. *Construct the projections of the pyramid, Example 1, having its base set in an inclined position, but with its edges SA and SD still parallel to the vertical plane,* Fig. 130.

It is evident, that with the exception of the inclination, the vertical projection of this solid is precisely the same as in the preceding example, and it is only necessary to show the same view of the pyramid in its new position. For this purpose, after having fixed the position of the point D, draw through this point a straight line DA, making with MN an angle equal to the desired inclination of the base of the pyramid. Then set off the distance DA, equal to that used in Example 1; erect a perpendicular on the center, and set off GS equal to the height of the pyramid. Transfer also from the first example the distance BG and CG to the corresponding points, and complete the figure by drawing the straight lines AS, BS, CS, and DS.

In constructing the plan of the pyramid in this position, it is to be remarked that since the edges SA and SD are still parallel to the vertical plane, and the point D remains unaltered, the projection of the points A, D, and S, will still be in the line MN. The position of A' is determined by the intersection of the perpendicular AA' with MN. The remaining points, B', C', etc., in the projection of the base, are found, in a similar manner, by the intersections raised from the corresponding points in the elevation, with lines drawn parallel to MN, at a distance (set off at o, p) equal to the width of the base. By joining all the contiguous points, the figure $A'B'C'D'E'F'$ is obtained representing the horizontal projection of the base, two of its sides, however, being dotted, as they must be supposed to be concealed by the body of the pyramid. The vertex S having been similarly projected to S', and joined by straight lines to the several angles of the base, the projection of the solid is completed.

INTERSECTIONS

If one surface meets another at some angle, an intersection is produced. Either surface may be plane, or curved. If both are plane, the intersection is a straight line; if one is curved, the intersection is a curve, except in a few special cases; and if both are curved, the intersection is usually curved. In the latter case, the

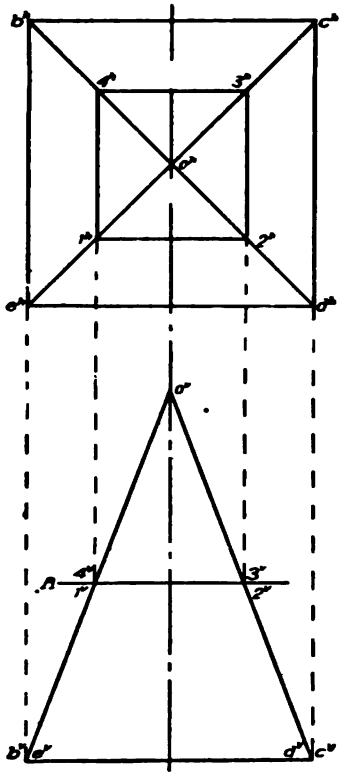


Fig. 131. Intersection of Plane and Square Pyramid

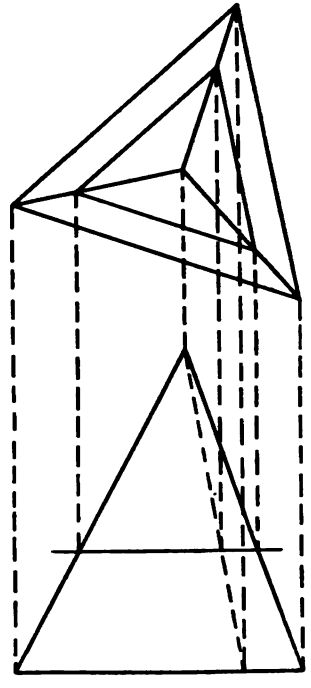


Fig. 132. Intersection of Plane and Triangular Pyramid

entire curve does not always lie in the same planes. If all points of any curve lie in the same plane, it is called a *plane curve*. A plane intersecting a curved surface must always give either a plane curve or a straight line.

Planes with Planes. In Fig. 131 a square pyramid is cut by a plane A parallel to the horizontal. This plane cuts from the pyra-

mid a four-sided figure, the four corners of which will be the points where A cuts the four slanting edges of the solid. The plane intersects edge ob at point 4^v in elevation. This point must be found in plan vertically above on the horizontal projection of line ob, that is, at point 4^h. Edge oe is directly in front of ob, so is shown in elevation as the same line, and plane A intersects oe at point 1^v in

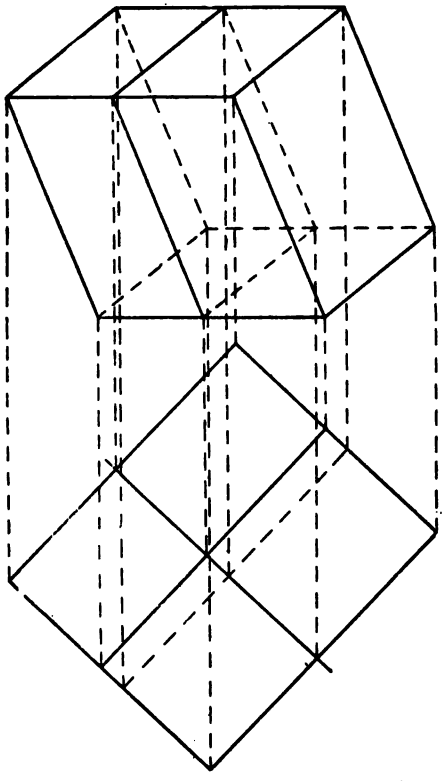


Fig. 133. Intersection of Plane and Prism

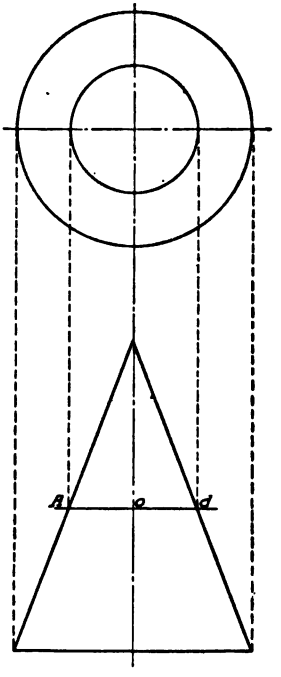


Fig. 134. Intersection of Plane and Cone

elevation, found in plan at 1^h. Points 3 and 2 are obtained in the same way. The intersection is shown in plan as the square 1-2-3-4, which is also its true size as it is parallel to the horizontal plane. In a similar way the intersections are found in Figs. 132 and 133. It will be seen that in these three cases where the planes are parallel to the bases, the sections are of the same shape as the bases, and have their sides parallel to the edges of the bases.

It is an invariable rule that when such a solid is cut by a plane parallel to its base, the section is a figure of the same shape as the base. If then in Fig. 134 a right cone is intersected by a plane parallel to the base the section must be a circle, the center of which in plan coincides with the apex. The radius must equal *o d*.

In Fig. 135 and Fig. 136 the cutting plane is not parallel to the base, hence the section will not be of the same shape as the base.

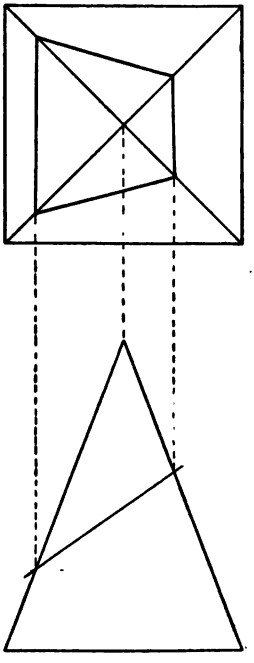


Fig. 135. Intersection of Plane and Square Pyramid

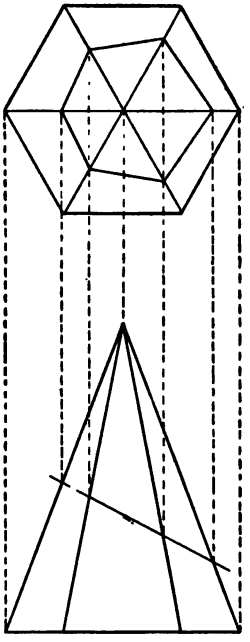


Fig. 136. Intersection of Plane and Hexagonal Pyramid

The intersections are found, however, in exactly the same manner as in the previous figures, by projecting the points where the plane intersects the edges in elevation, on to the other view of the same line.

ILLUSTRATIVE EXAMPLES

1. Find the horizontal projection of a transverse section of the pyramid of Fig. 130, made by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let all the sides of the base be at an angle with *M N*, Fig. 137.

Having drawn the vertical SS', the center line of the figures, its point of intersection with the line MN is the center of the plan. Since none of the sides of the base are to be parallel with MN, draw a diameter $A'D'$ making the required angle with MN, and from the points A' and D' proceed to set out the angular points of the hexagon, as in Fig. 130. Then join the angular points which are diametrically opposite and project the figure thus obtained upon the vertical plane, as shown.

Now, if the cutting plane be represented by the line ad in the elevation, it is obvious that it will expose, as the section of the pyramid, a polygon whose angular points being the intersections of the various edges with the cutting plane, will be projected in perpendiculars drawn from the points where it meets these edges respectively. From the points a, f, b, etc., raise the perpendiculars aa', ff', bb', etc., to meet the lines $A'D'$, $F'C'$, $B'E'$, etc. When the contiguous points of intersection of these lines are joined, a six-sided figure will be formed which will represent the section required. The edges FS and ES being concealed in the elevation, but necessary for the construction of the plan, have been expressed in dotted lines, as is also the portion of the pyramid situated above the cutting plane which, though supposed to be removed, is necessary in order to draw the lines representing the edges.

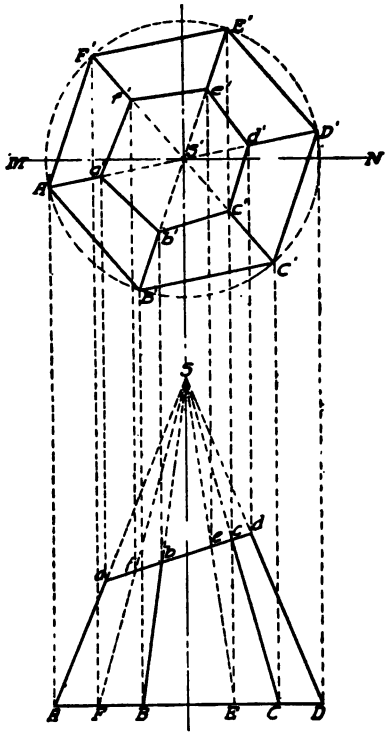


Fig. 137. Frustum of Hexagonal Pyramid

2. Find the horizontal projection of the transverse section of a regular five-sided pyramid, cut by a plane perpendicular to the vertical, but inclined at an angle to the horizontal plane of projection; and let one edge of the pyramid, BS, be in a plane

perpendicular to both the horizontal and the vertical planes of projection, as shown in Fig. 138.

The plan of the pyramid is constructed by describing from the center S' a circle circumscribing the base, and from B' dividing the circumference into five equal parts, and joining the contiguous points of division by straight lines. These form the polygon $A'B'C'D'E'$, whose angles, when joined to the center S', show the projections of the edges of the pyramid. Then, following the method above explained, the elevation and the horizontal projection of the section made by the plane ac are obtained. But that method will not suffice for the determination of the point b', because the perpendicular let fall from the corresponding point b, in the elevation, coincides with the projection of the edge BS. Let the pyramid supposedly be turned a quarter of a revolution round its axis; the line $B'S'$ will then have assumed the position $S'b^2$. Project the point b^2 to b^3, and join Sb^3. Then since the required point must also be conceived to have described a quarter of a circle in a plane parallel to the horizontal plane, and that its new position must be in the line Sb^3, it is obvious that its vertical projection is the point b^4, the intersection of a horizontal line drawn through b with the line Sb^3. The distance bb^4 may then be used to determine the distance from S' to b', and determines the position of the latter point in the plan; or, following a more methodical process, by projecting the point b^4 to b^5, and describing a circle from the center S' passing through b^5, its intersection with $B'S'$ is the point sought.

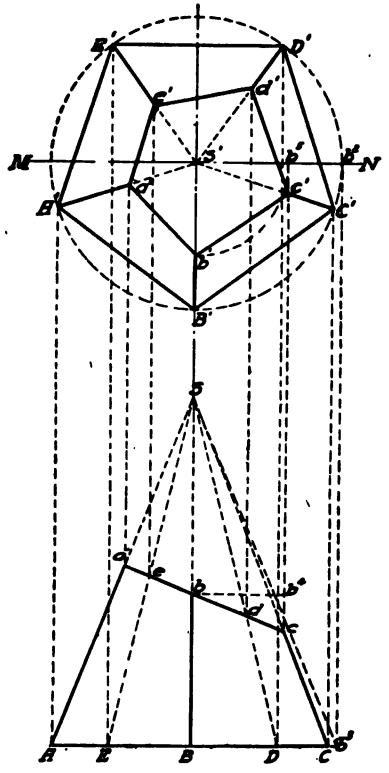


Fig. 138. Frustum of Pentagonal Pyramid

Planes with Cones or Cylinders. Sections cut by a plane from a cone have already been defined as *conic sections*. These sections may be any of the following: two straight lines, circle, ellipse, parabola, hyperbola. All except the parabola and hyperbola may also be cut from a cylinder.

Methods have previously been given for constructing the ellipse, parabola, and hyperbola, without projections; it will now be shown that they may be obtained as actual intersections.

Ellipse. In Fig. 139 the plane cuts the cone obliquely. To find points on the curve in plan take a series of horizontal planes $x\,y\,z$, etc., between points c^v and d^v. One of these planes, as w, should be taken through the center of $c\,d$. The points c and d must be points on the curve, since the plane cuts the two contour elements at these points. Contour elements are those forming the outline. The horizontal projections of the contour elements will be found in a horizontal line passing through the center of the base; hence the horizontal projection of c and d will be found on this center line, and will be the extreme ends of the curve.

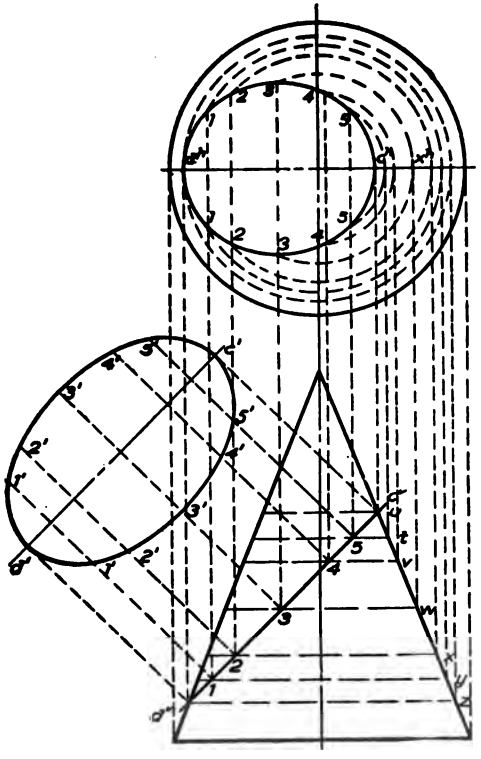


Fig. 139. Ellipse—Section from a Cone

The plane x cuts the surface of the cone in a circle, as it is parallel to the base, and the diameter of the circle is the distance between the points where x crosses the two contour elements. This circle, lettered x on the plan, has its center at the horizontal projection of the apex. The circle x and the curve cut by the plane are both on

the surface of the cone, and their vertical projections intersect at the points 2-2. Point 2 on the elevation then represents two points which are shown in plan directly above on the circle x, and are points on the required intersection. Planes y and z, and as many more as may be necessary to determine the curve accurately, are used in the same way. The curve found is an ellipse. The student will readily see that the true size of this ellipse is not shown in the plan, for the plane containing the curve is not parallel to the horizontal.

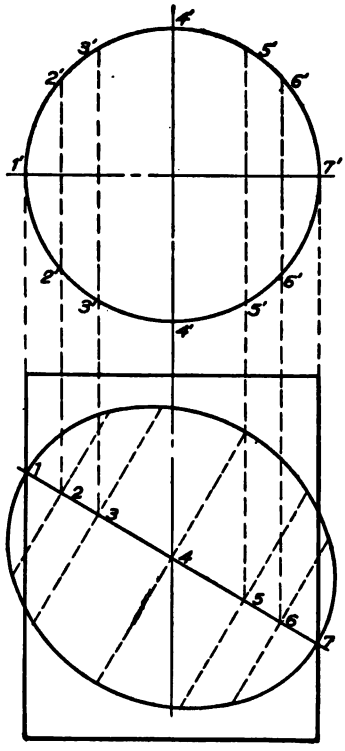


Fig. 140. Ellipse—Section from a Cylinder

In order to find the *actual size of the ellipse*, it is necessary to place its plane in a position parallel either to the vertical or to the horizontal. The actual length of the long diameter of the ellipse must be shown in elevation, $c^v d^v$, because the line is parallel to the vertical plane. The plane of the ellipse then may be revolved about $c^v d^v$ as an axis until it becomes parallel to V, when its true size will be shown. For the sake of clearness of construction, $c^v d^v$ is imagined moved over to the position $c' d'$, parallel to $c^v d^v$. The lines 1-1, 2-2, 3-3 on the plan show the true width of the ellipse, as these lines are parallel to H, but are projected closer together than their actual distances. In elevation these lines are shown as the points 1, 2, 3, at their true distance apart. Hence if the ellipse is revolved around its axis $c^v d^v$, the distances 1-1, 2-2, 3-3 may be laid off on lines perpendicular to $c^v d^v$, and the true size of the figure be shown.

In Fig. 140 a plane cuts a cylinder obliquely. This is a simpler case, as the horizontal projection of the curve coincides with the base of the cylinder. To obtain the true size of the section, which is an ellipse, any number of points are assumed on the plan and

projected down on the cutting plane, at 1, 2, 3, etc. The lines drawn through these points perpendicular to 1′-7′ are made equal in length to the corresponding distances 2′-2′, 3′-3′, etc., on the plan, because 2′-2′ is the true width of curve at 2.

Parabola. If a cone is intersected by a plane which is parallel to only one of the elements, as in Fig. 141, the resulting curve is

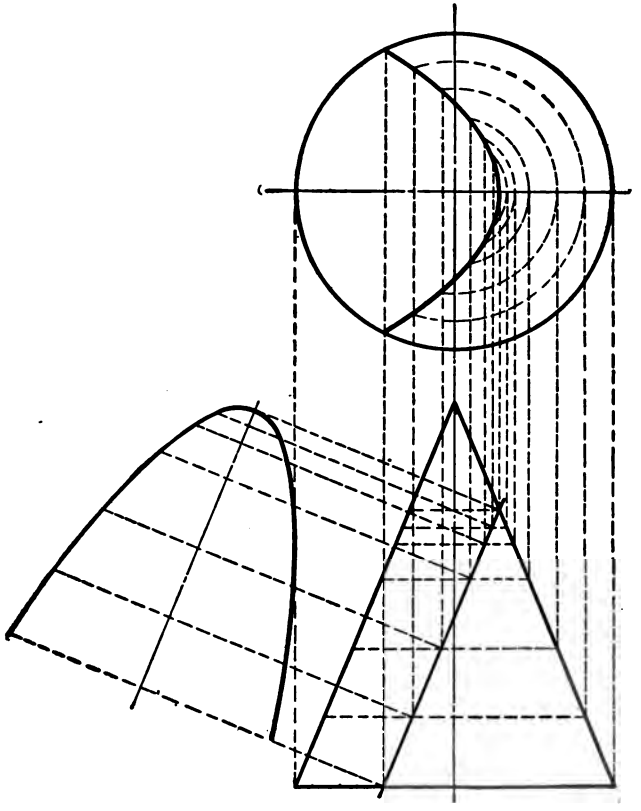


Fig. 141. Parabola—Section from a Cone

the *parabola*, the construction of which is exactly similar to that for the ellipse, as given in Fig. 139. If the intersecting plane is parallel to more than one element, or is parallel to the axis of the cone, a hyperbola is produced.

In Fig. 142, the vertical plane *A* is parallel to the axis of the cone. In this instance the curve when found will appear in its true

size, as plane A is parallel to the vertical. Observe that the highest point of the curve is found by drawing the circle X on the plan tangent to the given plane. One of the points where this circle crosses the diameter is projected down to the contour element of the cone, and the horizontal plane X drawn. Intermediate planes Y, Z, etc., are chosen, and corresponding circles drawn in plan. The points where these circles are crossed by the plane A are points on the curve, and these points are projected down to the elevation on the planes Y, Z, etc.

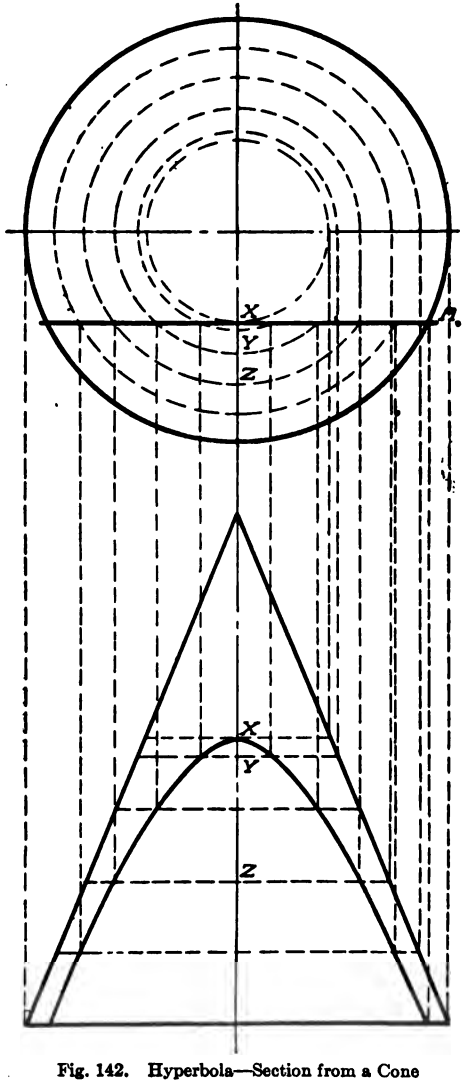


Fig. 142. Hyperbola—Section from a Cone

DEVELOPMENT OF SURFACES

General Details of Process. A surface may be considered as formed by the motion of a line. Any length of line moved sidewise in any direction will form a surface, of a width equal to the length of the line, and of a length equal to the distance over which the line is moved. There are two different classes of surfaces; namely, those formed by a moving straight line, and those formed by a moving curved line.

In some construction work, patterns of different faces or of the whole surface must be made; in stone cutting, for example,

there must be a pattern giving the shape of any irregular surface, and in sheet-metal work a pattern must be made such that, when a sheet is cut, it can be so formed that it will be of the same shape as the original object.

This pattern making, or the laying out of a complete surface on one plane, is called the development of the surface. Any surface

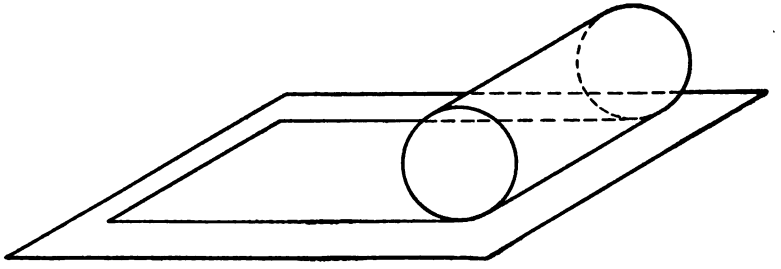


Fig. 143. Development of a Right Cylinder Rolled Out on a Plane

which can be smoothly wrapped about by a sheet of paper, can be developed. Figures made up of planes and single curved surfaces only would be of this nature. Double curved surfaces and warped surfaces cannot be developed, and patterns of such surfaces, when desired, must be made by an approximate method which requires two or more pieces to make the complete pattern.

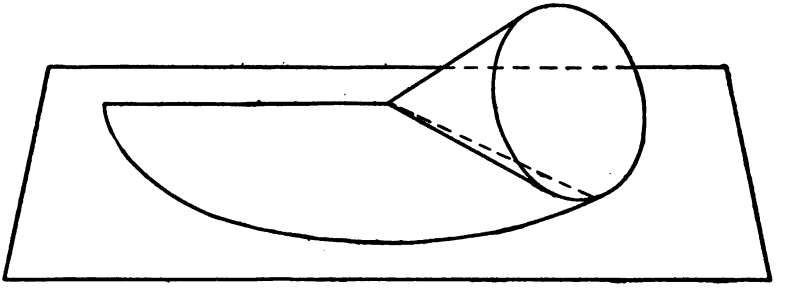


Fig. 144. Development of a Right Cone Rolled Out on a Plane

By finding the true size of all the faces of an object made up of planes, and joining them in order at their common edges, the developed surface will be formed. The best way to do this is to find the true length of the edges of the object.

Right Cylinder. In Fig. 143 is represented a right cylinder rolling on a plane. The development is formed by one complete

revolution of the cylinder and is a rectangle, the width being equal to the height of the cylinder and the length to the circumference.

Right Cone. In Fig. 144 is represented a right cone rolling out its development, which is a sector of a circle. The arc equals the circumference of the circle forming the base of the cone, and the radius equals the slant height.

The projections of any object must be drawn before the development can be made, but it is necessary only to draw such views as are required for finding the lengths of elements, and true sizes of cut surfaces.

Rectangular Prism. In order to find the development of the rectangular prism in Fig. 145, the back face, 1-2-7-6, is supposed

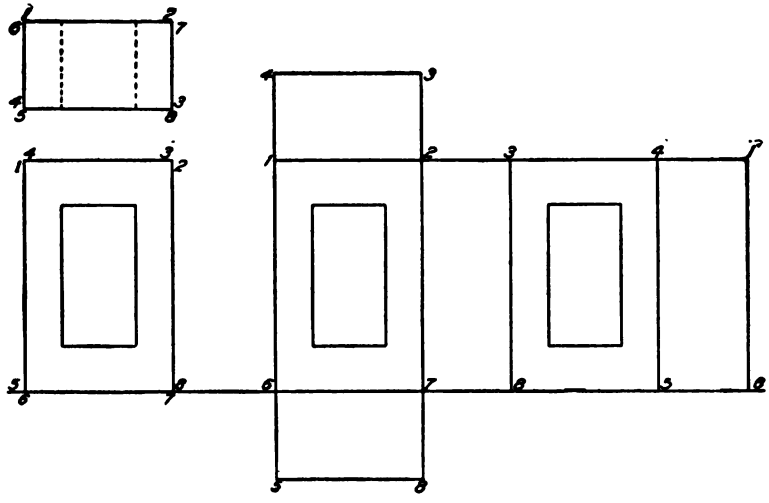


Fig. 145. Development of Hollow Rectangular Prism

to be placed in contact with some plane, then the prism turned on the edge 2-7 until the side 2-3-8-7 is in contact with the same plane, and this process continued until all four faces have been placed on the same plane. The rectangles 1-2-3-4 and 6-7-8-5 are for the top and bottom, respectively. The development then is the exact size and shape of a covering for the prism. If a rectangular hole is cut through the prism, the openings in the front and back faces will be shown in the development in the centers of the two broad faces.

The development of a right prism, then, consists of as many rectangles joined together as the prism has sides, these rectangles being the exact size of the faces of the prism, and in addition two polygons the exact size of the bases. It will be found helpful in developing a solid to number or letter all of the corners on the projections, then designate each face when developed in the same way as in the figure.

Cone. If a cone be placed on its side on a plane surface, one element will rest on the surface. If now the cone be rolled on the

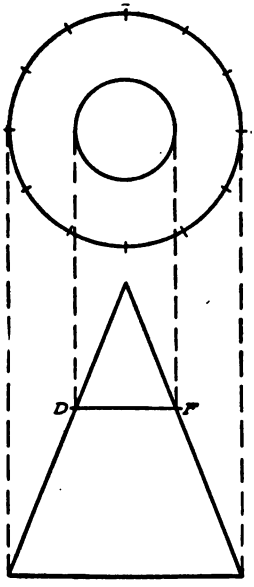


Fig. 146. Plan and Elevation of Cone

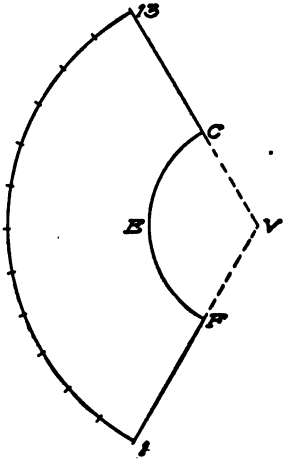


Fig. 147. Development of Cone

plane, the vertex remaining stationary until the same element is in contact again, the space rolled over will represent the development of the convex surface of the cone. Fig. 146 is a cone cut by a plane parallel to the base. In Fig. 147, let the vertex of the cone be placed at V, and one element of the cone coincide with $VF1$. The length of this element is taken from the elevation, Fig. 146, of either contour element. All of the elements of the cone are of the same length, so that when the cone is rolled, each point of the base as it touches the plane will be at the same distance from the vertex. From this it follows that in the development of the base,

the circumference will become the arc of a circle of radius equal to the length of an element, and of a length equal to the distance around the base. To find this length divide the circumference of the base in the plan into any number of equal parts, say twelve, and lay off twelve such spaces, 1 . . . . 13 along an arc drawn with radius equal to $V1$; join 1 and 13 with V, and the resulting sector is the development of the cone from vertex to base. In order to represent on the development the circle cut by the section plane DF, draw, from the vertex V as a center and with VF as a radius, the arc FC. The development of the frustum of the cone will be a portion of a circular ring. This of course does not include the development of the bases, which would be simply two circles the same sizes as shown in plan.

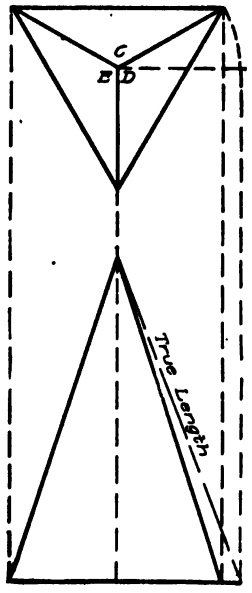


Fig. 148. Plan and Elevation of Triangular Pyramid

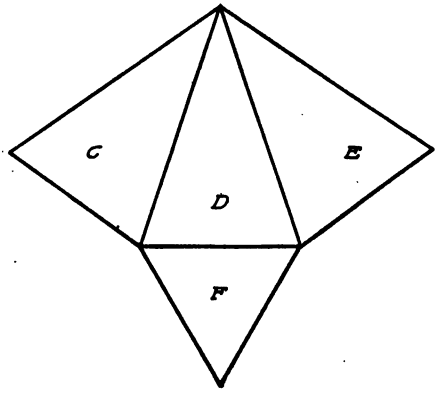


Fig. 149. Development of Triangular Pyramid

Regular Triangular Pyramid. Fig. 148 represents the plan and elevation of a regular triangular pyramid, and Fig. 149 its development. If face C is placed on the plane its true size will be shown in the development. The true length of the base of triangle C is shown in the plan. As the slanting edges, however, are not parallel to the vertical, their true length is not shown in elevation but must be obtained by the method given on page 88, as indicated in Fig. 148. The triangle may now be drawn in its full size at C in the development, and as the pyramid is regular, two other equal triangles,

D and *E*, may be drawn to represent the other sides. These, together with the base *F*, constitute the complete development.

Truncated Circular Cylinder. If a truncated circular cylinder is to be developed, or rolled upon a plane, the elements, being parallel, will appear as parallel lines, and the base line being perpendicular to the elements, will appear as a straight line of length equal to the circumference of the base. The base of the cylinder in Fig. 150 is divided into twelve equal parts, 1, 2, 3, etc., and commencing at point 1 on the development, these twelve equal spaces are laid off along the straight line, giving the total width.

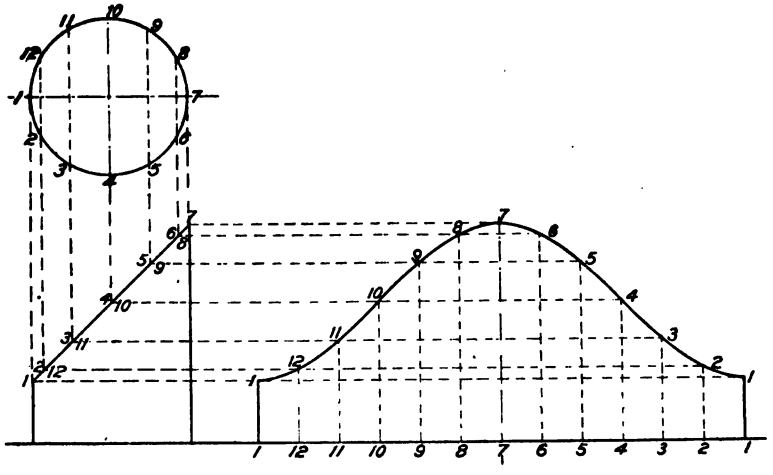


Fig. 150. Projections and Development of Truncated Cylinder

Draw in elevation the elements corresponding to the various divisions of the base, and note the points where they intersect the oblique plane. As the cylinder is rolled beginning at point 1, the successive elements, 1, 12, 11, etc., will appear at equal distances apart, and equal in length to the lengths of the same elements in elevation. Thus point number 10 on the development is found by projecting horizontally across from 10 in elevation. It will be seen that the curve formed is symmetrical, the half on the left of 7 being similar to that on the right. The development of any similar surface may be found in the same manner.

The principle of cylinder development is used in laying out elbow joints, pipe ends cut off obliquely, etc. In Fig. 151 is shown

plan and elevation of a three-piece elbow and collar, and developments of the four pieces. In order to construct the various parts making up the joint, it is necessary to know what shape and size must be marked out on the flat sheet metal so that when cut out and rolled up the three pieces will form cylinders with the ends fitting together as required. Knowing the kind of elbow desired, first draw the plan and elevation, and from these make the develop-

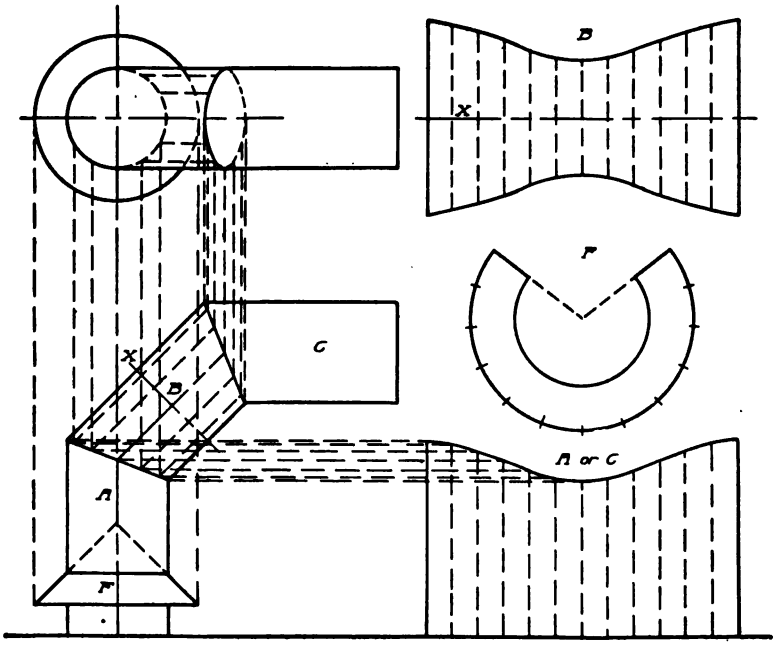


Fig. 151. Plan, Elevation, and Development of Three-Piece Elbow and Collar

ments. Let the lengths of the three pieces *A*, *B*, and *C* be the same on the upper outside contour of the elbow, the piece *B* at an angle of 45 degrees; the joint between *A* and *B* bisects the angle between the two lengths, and in the same way the joint between *B* and *C*. The lengths *A* and *C* will then be the same and one pattern will answer for both. The development of *A* is made exactly as just explained for Fig. 150, and this is also the development of *C*.

It should be borne in mind that in developing a cylinder the base must always be at right angles to the elements, and if the cylinder as given does not have such a base, it becomes necessary

to cut the cylinder by a plane perpendicular to the elements, and use the intersection as a base. This point must be clearly understood in order to proceed intelligently. A section at right angles to the elements is the only section which will unroll in a straight line, and is, therefore, the section from which the other sections must be developed. As *B*, Fig. 151, has neither end at right angles to its length, the plane *X* is drawn at the middle and perpendicular to the length. *B* has the same diameter as *C* and *A*, so the section cut by *X* will be a circle of the same diameter as the base of *A*, and is shown in the development at *X*.

The elements on *B* are drawn from the points where the elements on the elevation of *A* meet the joint between *A* and *B*, and are equally spaced as shown on the plan of *A*. Commencing with the left-hand element in *B*, the length of the upper element between *X* and the top corner of the elbow is laid off above *X*, giving the first point in the development of the end of *B* fitting with *C*. The lengths of the other elements in the elevation of *B* are measured in the same way and laid off from *X*. The development of the other end of the piece *B* is laid off below *X*, using the same distances, since *X* is half way between the ends. The development of the collar is simply the development of the frustum of a cone, which has already been explained, Fig. 147. The joint between *B* and *C* is shown in plan as an ellipse, the construction of which the student should be able to understand from a study of the figure.

ISOMETRIC PROJECTION

Isometric of a Cube. In orthographic projection an object has been represented by two or more projections; another system, called isometrical drawing, is often used to show in one view the three dimensions of an object, length (or height), breadth, and thickness. An isometrical drawing of an object, as a cube, is called for brevity the isometric of the cube.

To obtain a view which shows the three dimensions in such a way that measurements may be taken from them, draw the cube in the simple position shown at the left, Fig. 152, with two faces parallel to *V;* the diagonal from the front upper right-hand corner to the back lower left-hand corner is indicated by the dotted line. Swing the cube around until the diagonal is parallel with *V*, as shown in the

second position. Here the front face is at the right. In the third position the lower end of the diagonal has been raised so that it is parallel to H, becoming thus parallel to both planes. The plan is found by the principles of projection, from the elevation and the preceding plan. The front face is now the lower of the two faces shown in the elevation. From this position the cube is swung around, using the corner as a pivot, until the diagonal is perpendicular to V but still parallel to H. The plan remains the same, except as regards position; while the elevation, obtained by projecting across from the previous elevation, gives the isometrical projection of the cube. The front face is now at the left.

Distinction between Isometric Projection and Isometric Drawing. In the last position, as one diagonal is perpendicular to V, it follows

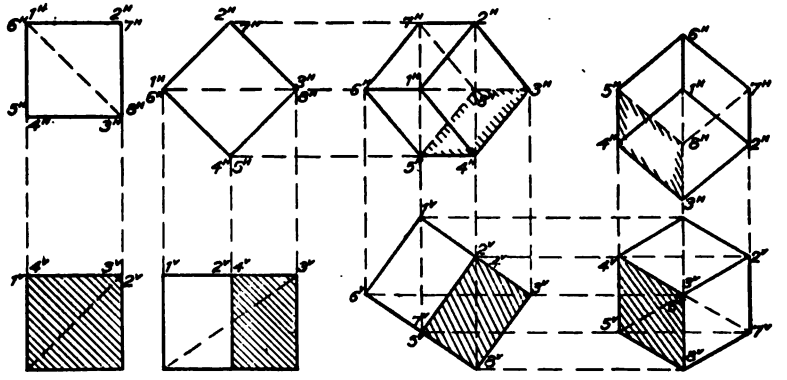


Fig. 152. Development of an Isometric of a Cube

that all the faces of the cube make equal angles with V, hence are projected on that plane as equal parallelograms. For the same reason all the edges of the cube are projected in elevation in equal lengths, but, being inclined to V, appear shorter than they actually are on the object. Since they are all equally foreshortened and since a drawing may be made at any scale, it is customary to make all the isometrical lines of a drawing full length. This will give the same proportions, and is much the simpler method. Herein lies the distinction between an isometric projection and an isometric drawing.

It will be noticed that the figure may be inscribed in a circle, and that the outline is a perfect hexagon. Hence the lines showing

breadth and length are 30-degree lines, while those showing height are vertical.

True Length of Lines. Fig. 153 shows the isometric of a cube 1 inch square. All of the edges are shown in their true length, hence

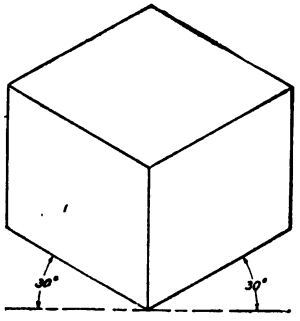


Fig. 153. Isometric of a Cube

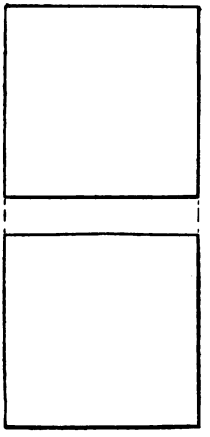


Fig. 154. Plan and Elevation of a Cube

all the surfaces appear of the same size. In the figure the edges of the base are inclined at 30 degrees with a T-square line, but this is not always the case. For rectangular objects, such as prisms, cubes, etc., the base edges are at 30 degrees only when the prism or cube is supposed to be in the simplest possible position. The cube in Fig. 153 is supposed to be in the position indicated by plan and elevation in Fig. 154, that is, standing on its base, with two faces parallel to the vertical plane.

If the isometric of the cube in the position shown in Fig. 155 were required, it could not be drawn with the base edges at 30 degrees; neither would these edges appear in their true lengths. It

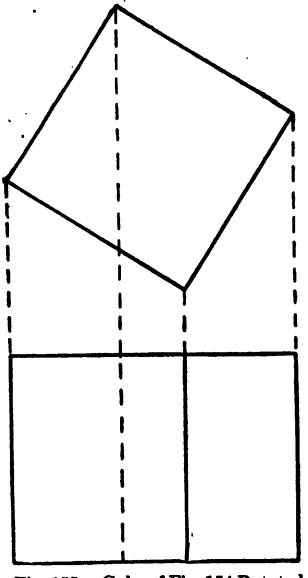


Fig. 155. Cube of Fig. 154 Rotated 30 Degrees with Vertical Plane

follows, then, that in isometrical drawing, true lengths appear only as 30-degree lines or as vertical lines. Edges or lines that in actual projection are either parallel to a T-square line or perpendicular to V, are drawn in isometric as 30-degree lines, full length; and those that are actually vertical are made vertical in isometric, also full length.

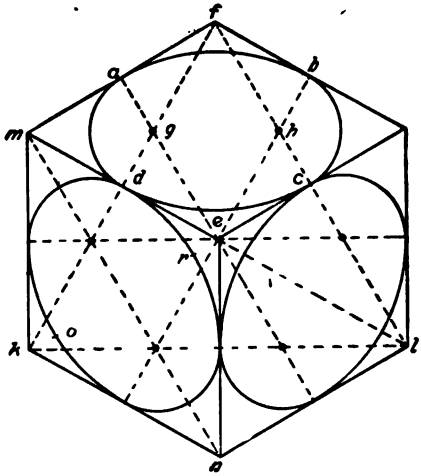


Fig. 156. Isometric of a Cube with Circles Inscribed on its Faces

Three Isometric Axes. In Fig. 152, lines such as the front vertical edges of the cube and the two base edges are called the *three isometric axes.* The isometric of objects in oblique positions, as in Fig. 155, can be constructed only by reference to their projections, by methods which will be explained in the section on "Oblique Projection", page 123.

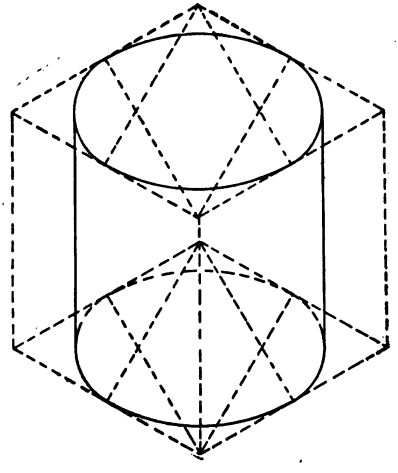


Fig. 157. Isometric of a Cylinder

Applications of Isometric Projections. In isometric drawing small rectangular objects are more satisfactorily represented than large curved ones. In woodwork, mortises and joints and various parts of framing are well shown in isometric. This system is used also to give a kind of bird's-eye view of mills or factories. It is also used in making sketches of small rectangular pieces of machinery, where it is desirable to give shape and dimensions in one view.

Characteristics of Various Isometrics. *Cube with Inscribed Circles.* Fig. 156 shows a cube with circles inscribed in the top and two side faces. The isometric of a circle is an ellipse the

exact construction of which would necessitate finding a number of points; for this reason an approximate construction by arcs of circles is often made. In the method, Fig. 156, four centers are used. Considering the upper face of the cube, lines are drawn from the obtuse angles f and e to the centers of the opposite sides. The intersections of these lines give points g and h, which serve as centers for the ends of the ellipse. With g as center and radius ga, the arc ad is drawn, and with f as center and radius fd, the arc

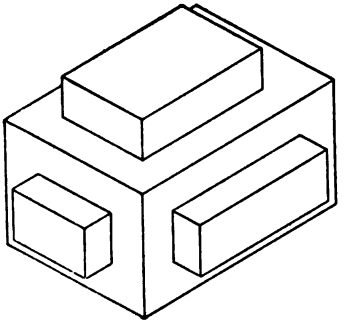


Fig. 158. Isometric of a Wooden Block

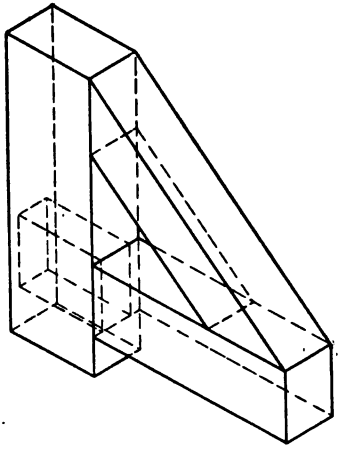


Fig. 159. Isometric of a Wooden Brace

dc is drawn; the ellipse is finished by using centers h and e. This construction is applied to all three faces.

Cylinder. Fig. 157 is the isometric of a cylinder standing on its base.

Blocks. Fig. 158 represents a block with smaller blocks projecting from three faces.

Framework. Fig. 159 shows a framework of three pieces, two at right angles and a slanting brace. The horizontal piece is mortised into the upright as indicated by the dotted lines.

House. In Fig. 160 the isometric outline of a house is represented, showing a dormer window and a partial hip roof; ab is a hip rafter, cd a valley. Let the pitch of the main roof be shown at B, and let m be the middle point of the top of the end wall of the house. Then, by measuring vertically up a distance ml equal to the vertical

height an shown at B, a point on the line of the ridge will be found at l. Line li is equal to bh, and ih is then drawn. Let the pitch of the end roof be given at A. This shows that the peak of the roof, or the end a of the ridge, will be back from the end wall a distance equal to the base of the triangle at A. Hence, lay off from l this distance, giving point a, and join a with b and x.

The height ke of the ridge of the dormer roof is known, and it must be found where this ridge will meet the main roof. The ridge must be a 30-degree line as it runs parallel to the end wall of the house and to the ground. Draw from e a line parallel to bh to meet a vertical through h and f. This point is in the vertical plane of

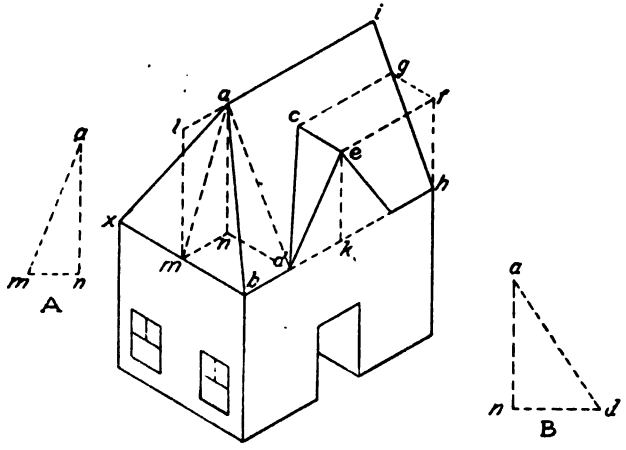


Fig. 160. Isometric Outline of a House

the end wall of the house, hence in the plane of ih. If now a 30-degree line be drawn from f parallel to xb, it will meet the roof of the house at g. The dormer ridge and fg are in the same horizontal plane, hence will meet the roof at the same distance below the ridge ai. Therefore draw the 30-degree line gc, and connect c with d.

Box with Cover. In Fig. 161 a box is shown with the cover opened through 150 degrees. The right-hand edge of the bottom shows the width, the left-hand edge shows the length and the vertical edge shows the height. The short edges of the cover are not isometric lines, hence are not shown in their true lengths; neither is the angle through which the cover is opened represented in its actual size.

The corners of the cover must then be determined by co-ordinates from an end view of the box and cover. As the end of the cover

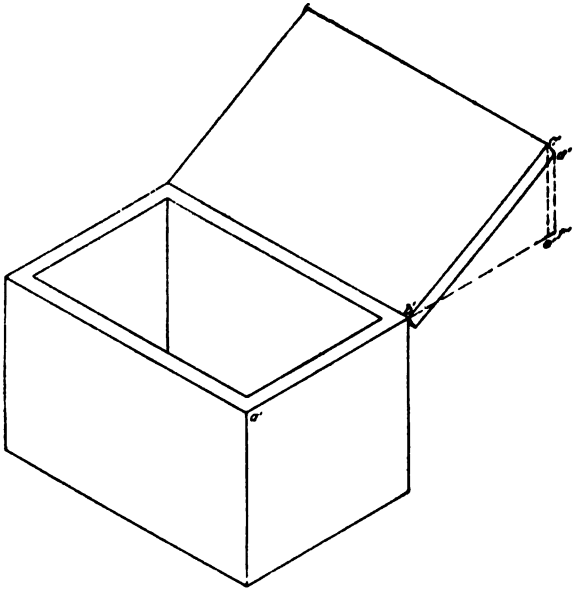


Fig. 161. Isometric of a Box and Cover

is in the same plane as the end of the box, the simple end view as shown in Fig. 162 will be sufficient. Extend the top of the box to the right, and from c and d let fall perpendiculars on ab produced, giving the points e and f. The point c may be located by means of the two distances or co-ordinates be and ec, and these distances will appear in their true lengths in the isometric view. Hence produce $a'b'$ to e' and f'; and from these points draw verticals $e'c'$ and $f'd'$; make $b'e'$ equal to be, $e'c'$ equal to ec; and similarly for d'. Draw the lower edge parallel to $c'd'$ and equal to it in length, and connect with b'.

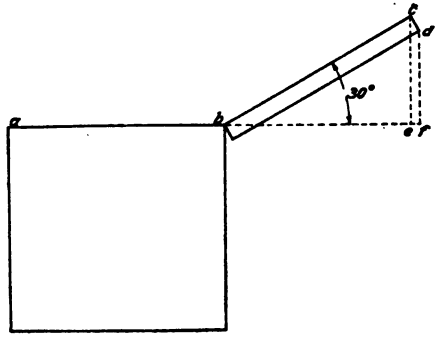


Fig. 162. End View of Box Shown in Fig. 161

It will be seen that in isometric drawing parallel lines always appear parallel. It is also true that lines divided proportionally maintain this same relation in isometric drawing.

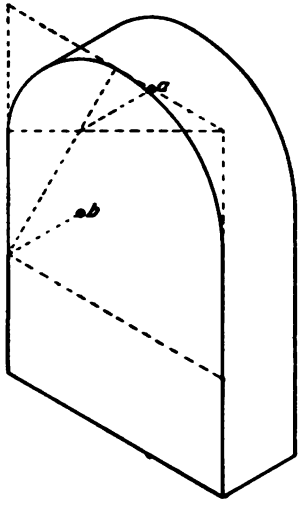


Fig. 163. Isometric of a Prism with Semicircular Top

Prism with Semicircular Top. Fig. 163 shows a block or prism with a semicircular top. Find the isometric of the square circumscribing the circle, then draw the curve by the approximate method. The centers for the back face are found by projecting the front centers back 30 degrees equal to the thickness of the prism, as shown at *a* and *b*.

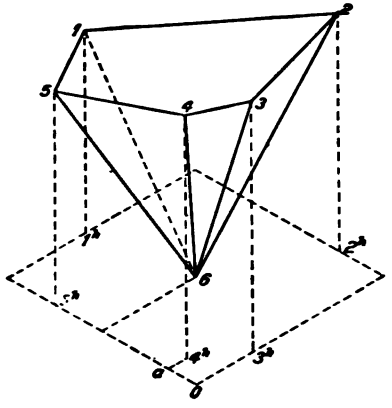


Fig. 165. Isometric of Fig. 164

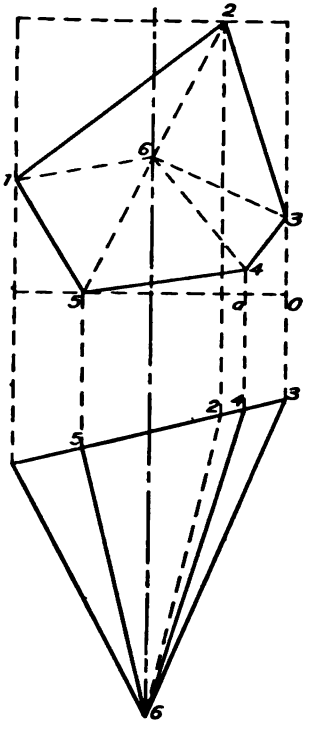


Fig. 164. Plan and Elevation of Oblique Pentagonal Pyramid

Pyramid. The plan and elevation of an oblique pentagonal pyramid are shown in Fig. 164. It is evident that none of the edges

of the pyramid can be drawn in isometric as either vertical or 30-degree lines; hence a system of co-ordinates must be used as shown in Fig. 165. This problem illustrates the most general case; and to locate some of the points three co-ordinates must be used, two at 30 degrees and one vertical.

Circumscribe, about the plan of the pyramid, a rectangle which shall have its sides respectively parallel and perpendicular to a T-square line.

The isometric of this rectangle can be drawn at once with 30-degree lines, as shown in Fig. 165, o being the same point in both figures. The horizontal projection of point 3 is found in isometric at 3^h, at the same distance from o as in the plan. That is, *any distance which in plan is parallel to a side of the circumscribing rectangle, is shown in isometric in its true length and parallel to the corresponding side of the isometric rectangle.* If point 3 were on the horizontal plane its isometric would be 3^h, but the point is at the vertical height above H given in the elevation; hence, lay off above 3^h this vertical height, obtaining the actual isometric of the point. To locate point 4, draw $4a$ parallel to the side of the rectangle; then lay off oa and $a4^h$, giving what may be called the isometric plan of 4. The

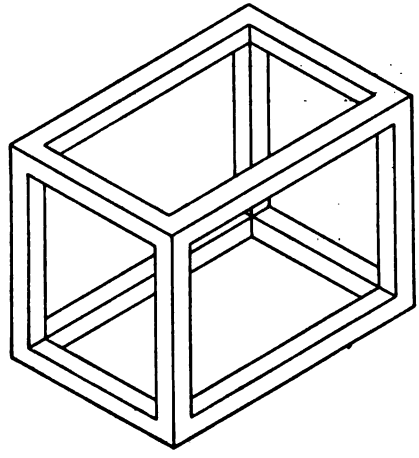


Fig. 166. Isometric of a Skeleton of a Box

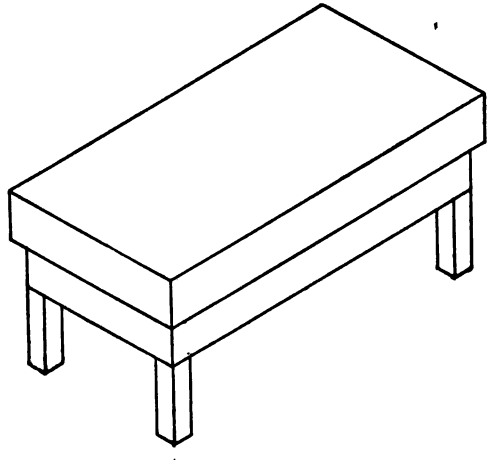


Fig. 167. Isometric of a Carpenter's Bench

vertical height taken from the elevation locates the isometric of the point.

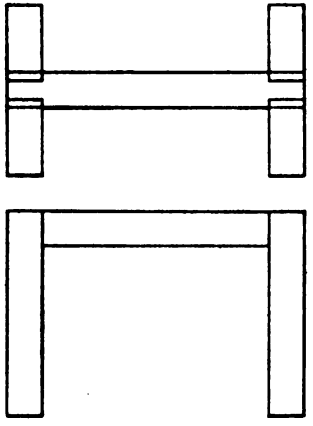


Fig. 168. Plan and Elevation of Sawhorse

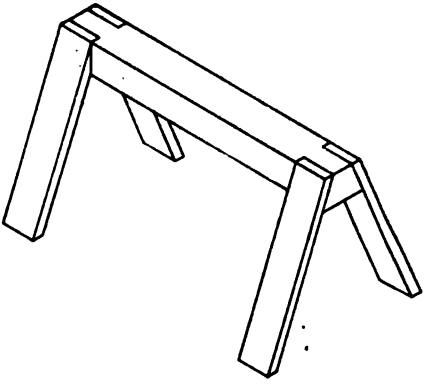


Fig. 169. Isometric of Fig. 168

In like manner all the corners of the pyramid, including the apex, are located. The rule is, *locate first in isometric the horizontal*

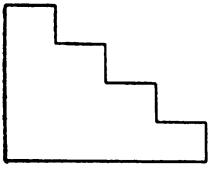


Fig. 170. End Elevation of Stairs

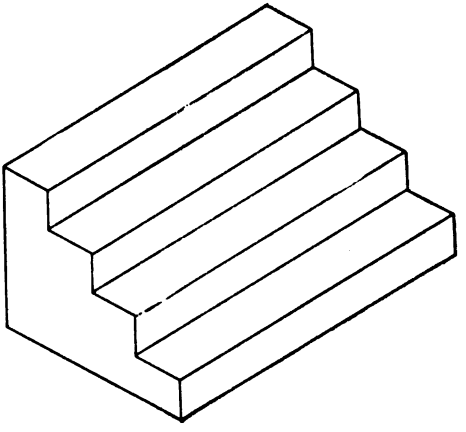


Fig. 171. Isometric of Stairs

projection of a point by one or two 30-degree co-ordinates; then vertically above this point, locate its height as taken from the elevation.

Figs. 166 to 173 give examples of the isometric of various objects.

Fig. 168 is the plan and elevation, and Fig. 169 the isometric, of a carpenter's sawhorse.

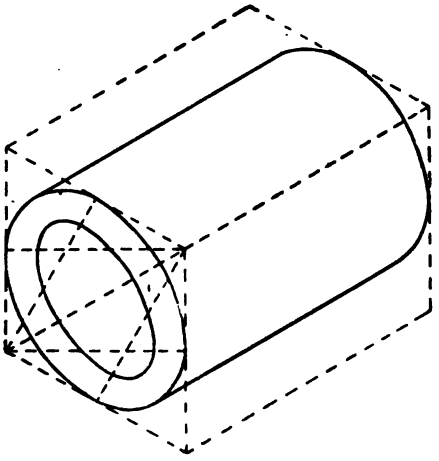


Fig. 172. Isometric of a Hollow Cylinder

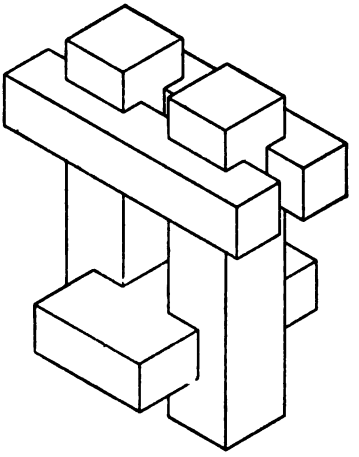


Fig. 173. Isometric of a Wooden Model

OBLIQUE PROJECTION

Comparison with Isometric Projection. In oblique projection, as in isometric, the end sought for is the same—a more or less complete representation, in one view, of any object. Oblique projection differs from isometric in that one face of the object is represented as if parallel to the vertical plane of projection, the others inclined to it. Another point of difference is that oblique projection cannot be deduced from orthographic projection, as is isometric.

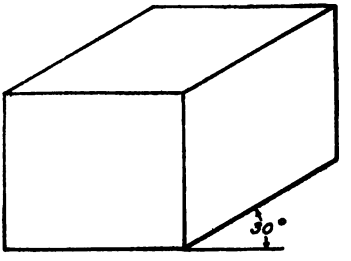


Fig. 174. Oblique View of Cube at 30 Degrees

Characteristics of Method. In oblique projection all lines in the front face are shown in their true lengths and in their true relation to one another, and lines which are perpendicular to this front face are shown in their true lengths at any angle that may be desired for any particular case. Lines not in the plane of the front face nor perpendicular to it must be determined by co-ordinates, as in isometric. It will be seen at once that this system

possesses some advantages over the isometric, as, for instance, in the representation of circles, as any circle or curve in the front face is actually drawn as such. Fig. 174, Fig. 175, and Fig. 176 show a cube in oblique projection with the 30-degree, 45-degree, and 60-degree slant, respectively. Fig. 177 shows a hollow cylinder in oblique projection. Figs 178, 179, 180, 182 are other examples of oblique projections. Fig. 180 is a crank arm.

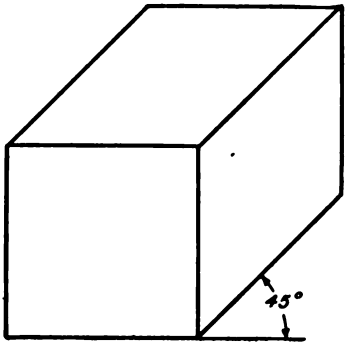


Fig. 175. Oblique View of Cube at 45 Degrees

The method of using co-ordinates for lines of which the true lengths are not shown, is illustrated by Figs 181 and 182. Fig. 182 represents the oblique projection of the two joists shown in plan and elevation in Fig. 181. The dotted lines in the elevation, Fig. 181, show the heights of the corners above the horizontal stick. The feet of these perpendiculars give the horizontal distances of the top corners from the end of the horizontal piece.

In Fig. 182 lay off from the upper right-hand corner of the front end a distance equal to the distance between the front edge of the

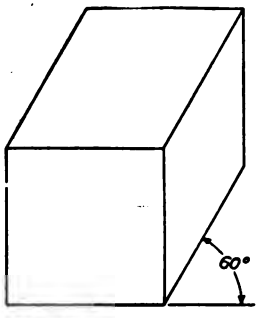


Fig. 176. Oblique View of Cube at 60 Degrees

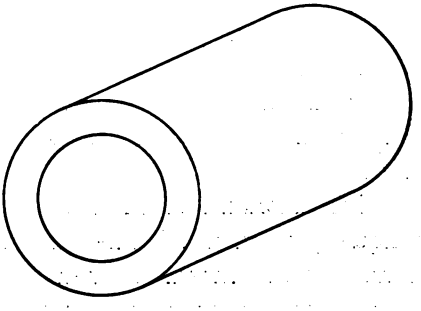


Fig. 177. Oblique View of Hollow Cylinder

inclined piece and the front edge of the bottom piece, Fig. 181. From this point draw a dotted line parallel to the length. The horizontal distances from the upper left corner to the dotted perpendicular are then marked off on this line. From these points verticals

are drawn, and made equal in length to the dotted perpendiculars of Fig. 181, thus locating two corners of the end.

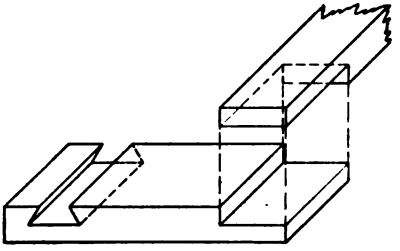


Fig. 178. Oblique View of a Miter Joint

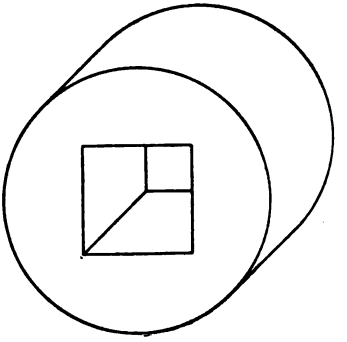


Fig. 179. Oblique View of Cylinder

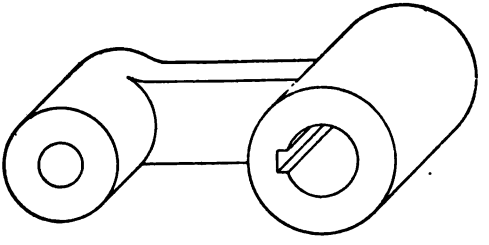


Fig. 180. Oblique View of Crank Shaft

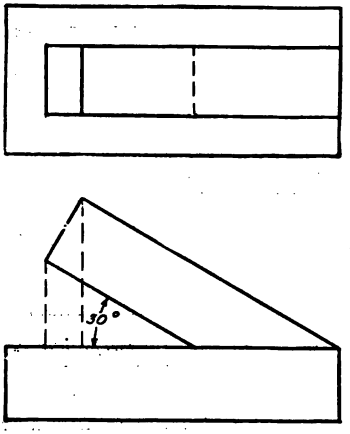


Fig. 181. Plan and Elevation of Wooden Brace

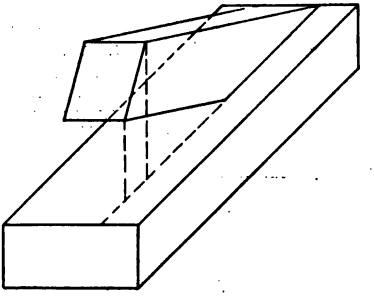


Fig. 182. Oblique View of Wooden Brace

LINE SHADING

Object of Line Shading. In finely finished drawings it is frequently desirable to make the various parts more readily seen by showing the graduations of light and shade on the curved surfaces. This is especially true of such surfaces as cylinders, cones, and spheres. The effect is obtained by drawing a series of parallel or converging lines on the surface at varying distances from one another. Sometimes draftsmen, themselves, vary the width of the lines. These lines are farther apart on the lighter portion of the surface, and closer together and heavier on the darker part.

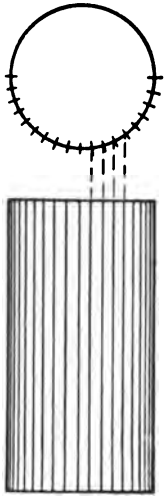


Fig. 183. Plan and Shaded Elevation of Cylinder

Fig. 183 shows a cylinder with elements drawn on the surface equally spaced on the plan. On account of the curvature of the surface, however, the elements are not equally spaced on the elevation, in order to give the effect of the graduations of light on the curved surface. The result is that in drawing the elevation of the cylinder, the distances between the elements are made gradually less from the center toward each side, thus giving a correct representation of the convexity of the cylinder. This effect is intensified by making the

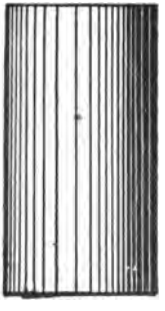


Fig. 184. Shaded Vertical Cylinder

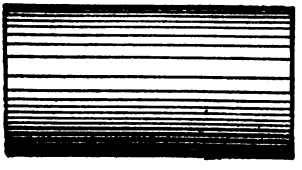


Fig. 185. Shaded Horizontal Cylinder

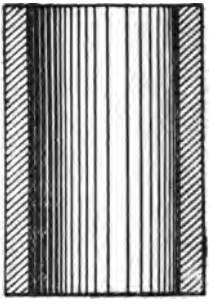


Fig. 186. Shaded Section of Hollow Cylinder

outside elements heavier as well as closer together, as shown in Figs. 184 to 190. Concavity is shown in the same manner, the

heavy shading always appearing on the left to indicate the deeper shadow, Figs. 186 and 188.

Fig. 184 is a cylinder showing the heaviest shade at the right, a method often used. Considerable practice is necessary to obtain good results; but in this, as in other portions of mechanical drawing, repetition is unavoidable. Fig. 185 represents a cylinder in a hori-

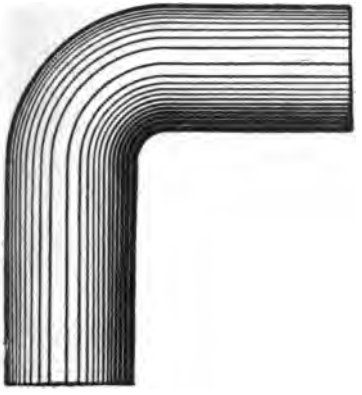


Fig. 187. Shaded Elbow Joint

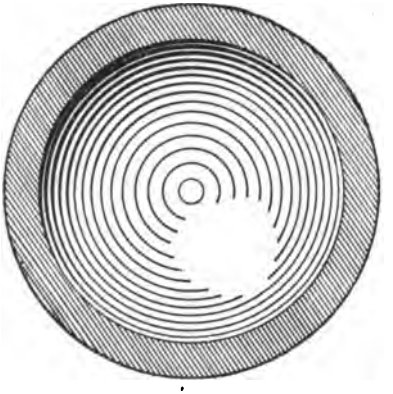


Fig. 188. Shaded Section of Hollow Sphere

zontal position, and Fig. 186 represents a section of a hollow vertical cylinder. Figs. 187 to 190 give other examples of familiar objects.

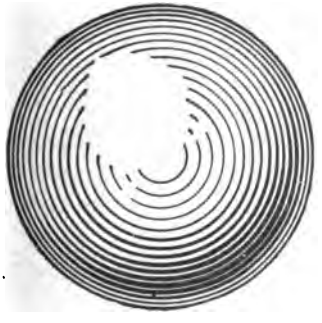


Fig. 189. Shaded Sphere

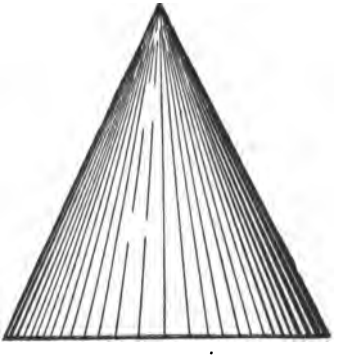


Fig. 190. Shaded Cone

In the elevation of the cone shown in Fig. 190 the shade lines should diminish in weight as they approach the apex. Unless this is done it will be difficult to avoid the formation of a blot at that point.

LETTERING

Types of Lettering. In the early part of this course, the inclined Gothic letter was described, and the alphabet given. The Roman, Gothic, and block letters are perhaps the most used for titles. These letters, being of comparatively large size, are generally made mechanically; that is, drawing instruments are used in their construction. In order that the letters may appear of the same height, some of them, owing to their shape, must be made a little higher than the others. This is the case with the letters curved at the top and bottom, such as C, O, S, etc., as shown somewhat exaggerated in Fig. 191. Also, the letter A should extend a little above, and V a little below, the guide lines, because if made of the same height as the others they will appear shorter. This is true of all capitals, whether of Roman, Gothic, or other alphabets. In the block letter, however, they are frequently all of the same size.

Size of Letters. There is no absolute size or proportion of letters, as the dimensions are regulated by the amount of space in which the letters are to be placed, the size of the drawing, the effect desired, etc. In some cases letters are made so that the height is greater than the width, and sometimes the reverse; sometimes the height and width are the same. This last proportion is the most common. Certain relations of width, however, should be observed. Thus, in whatever style of alphabet used, the W should be the widest letter; J the narrowest, M and T the next widest to W, then A and B. The other letters are of about the same width.

Vertical Gothic. In the vertical Gothic alphabet, the average height is that of B, D, E, F, etc., and the additional height of the curved letters and of the A and V is very slight. The horizontal cross lines of such letters as E, F, H, etc., are slightly above the center; those of A, G, and P slightly below.

Inclined Gothic. For the inclined letters, Fig. 192, 60 degrees is a convenient angle, although they may be at any other angle suited to the convenience or fancy of the draftsman. Many draftsmen use an angle of about 70 degrees.

Roman. The letters of the Roman alphabet, whether vertical, Fig. 193, or inclined, Fig. 194, are quite ornamental in effect if well made, the inclined Roman being a particularly attractive letter,

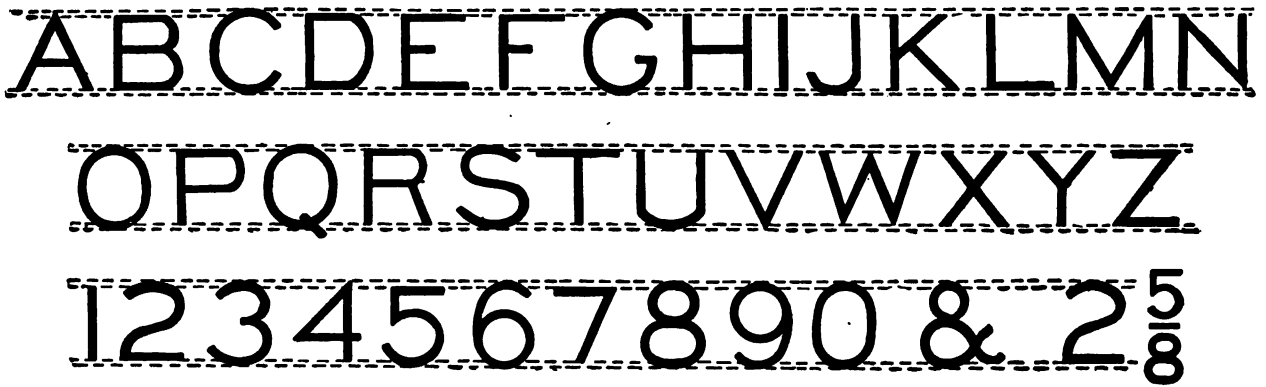


Fig. 191. Vertical Gothic Letters and Figures

Fig. 192. Inclined Gothic Letters and Figures

Fig. 193. Vertical Roman Letters and Figures

Fig. 194. Inclined Roman Letters and Figures

although rather difficult to make. The block letter, Fig. 195, is made on the same general plan as the Gothic, but much heavier. Small squares are taken as the unit of measurement, as shown. The use of this letter is not advocated for general work, although

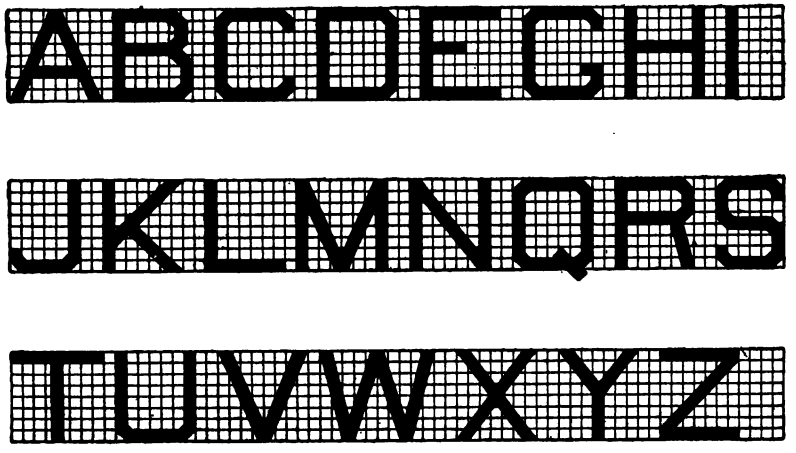


Fig. 195. Block Letters

if made merely in outline the effect is pleasing. The styles of numbers, corresponding with the alphabets of capitals given here, are also inserted. When a fraction, such as $2\frac{5}{8}$ is to be made, the proportion should be about as shown. For small letters, usually

Fig. 196. Vertical Gothic Lower-Case Letters

called lower-case letters, the height may be made about two-thirds that of the capitals. This proportion, however, varies in special cases.

Lower-Case Letters. The principal lower-case letters in general use among draftsmen are shown in Figs. 196, 197, 198, and 199.

The Gothic letters shown in Figs 196 and 197 are much easier to make than the Roman letters in Figs. 198 and 199. These letters,

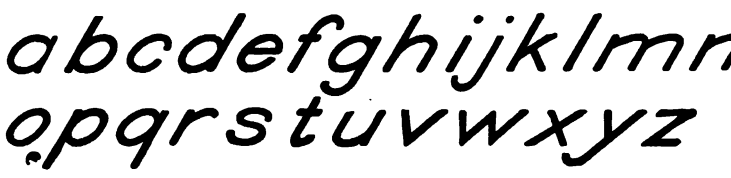


Fig. 197. Inclined Gothic Lower-Case Letters

however, do not give as finished an appearance as the Roman. As has already been stated in Mechanical Drawing, Part I, the inclined letter is easier to make because slight errors are not so apparent.

Fig. 198. Vertical Roman Lower-Case Letters

Spacing. One of the most important points to be remembered, in lettering is the spacing. If the letters are finely executed but

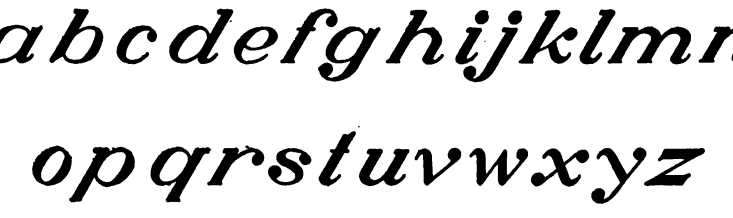


Fig. 199. Inclined Roman Lower-Case Letters

poorly spaced, the effect is not good. To space letters correctly and rapidly requires considerable experience; and rules are of little

Fig. 200. Sample of Letter Spacing

value on account of the many combinations in which letters are found. A few directions, however, may be found helpful. For

instance, take the word TECHNICALITY, Fig. 200. If all the spaces were made equal, the space between the L and the I would appear to be too great, and the same would apply to the space between the I and the T. The space between the H and the N and that between the N and the I would be insufficient. Usually, when the vertical side of one letter is followed by the vertical side of another, as in H E, H B, I R, etc., the maximum space should be allowed. Where T and A come together the least space is given, for in this case the top of the T frequently extends over the bottom of the A. In general, the spacing should be such that a uniform appearance is obtained. For the distances between words in a sentence, a space of about 1½ the width of the average letter may be used. The space, however, depends largely upon the desired effect.

Penciling before Inking. For large titles, such as those placed on charts, maps, and some large working drawings, the letters should be penciled before inking. If the height is made equal to the width, considerable time and labor will be saved in laying out the work. This is especially true with such Gothic letters as O, Q, C, etc., as these letters may then be made with compasses. If the letters are of sufficient size, the outlines may be drawn with the ruling pen or compasses, and the spaces between filled in with a fine brush.

Titles for Working Drawings. The titles for working drawings are generally placed in the lower right-hand corner. Usually a draftsman has his choice of letters, mainly because after he has become used to making one style he can do it rapidly and accurately. However, in some drafting rooms the head draftsman decides what lettering should be used. In making these titles, the different alphabets are selected to give the best results without spending too much time. In most work the letters are made in straight lines, although frequently a portion of the title is found lettered on an arc of a circle.

In Fig. 201 is shown a title having the words CONNECTING ROD lettered on an arc of a circle. To do this work requires considerable patience and practice. First, draw the vertical center line as shown at *C* in Fig. 201, then, draw horizontal lines for the horizontal letters. The radii of the arcs depend upon the general

arrangement of the entire title, and this is a matter of taste. The difference between the arcs should equal the height of the letters. After the arc is drawn, the letters should be sketched in pencil to find their approximate positions. After this is done, draw radial lines from the center of the letters to the center of the arcs. These

Fig. 201. Sample Title

lines will be the centers of the letters, as shown at *A*, *B*, *D*, and *E*. The vertical lines of the letters should not radiate from the center of the arc, but should be parallel to the center lines already drawn; otherwise the letters will appear distorted. Thus, in the letter *N*.

Fig. 202. Sample Title

the two verticals are parallel to the line *A*. The same applies to the other letters in the alphabet. In making the curved letters such as O and C, the centers of the arcs will fall upon these center lines; and if the compasses are used, the lettering is a comparatively simple matter. In Fig. 202 is shown another title in which all the letters are in horizontal lines.

PLATES

Plates IX to XV, inclusive, are to be drawn by the student for practice in applying the principles of orthographic projection, intersections and developments, isometric and oblique projection, and for practice in lettering. These plates are to be made 11 inches by 15 inches outside, with a margin of ½ inch, making the clear space for the drawing 10 inches by 14 inches. All the plates are to be inked.

PLATE IX

After laying out the border line on the plate, draw a ground line horizontally across the upper part of the plate, 3 inches below the upper border line. On this ground line six figures, spaced as regularly as possible, are to be drawn, as follows:

1. Draw the projections of a line $1\frac{1}{2}$ inches long which is parallel to both planes, 1 inch above the horizontal, and $\frac{3}{4}$ inch from the vertical.

2. Draw the plan and elevation of a line $1\frac{1}{2}$ inches long which is perpendicular to the horizontal plane and 1 inch from the vertical. Lower end of line is $\frac{1}{2}$ inch above H.

3. Draw the projections of two intersecting lines: one 2 inches long to be parallel to both planes, 1 inch above H, and $\frac{3}{4}$ inch from the vertical; and the other to be oblique to both planes and of any desired length.

NOTE. The idea for drawing the three figures referred to in 1, 2, and 3 can be obtained from Figs. 104 and 105 in this textbook.

4. Find the true length of a line whose vertical projection is $1\frac{1}{4}$ inches long, the left end on the ground line and inclined at 30 degrees. The horizontal projection has the left end $\frac{1}{2}$ inch from V, and the right $1\frac{1}{2}$ inches from V.

5. Find the true length of a line whose horizontal projection is 1 inch long, whose right end is $\frac{1}{2}$ inch above the ground line, and inclined at 60 degrees. The vertical projection has the right end $\frac{1}{2}$ inch below the ground line and the left 1 inch.

6. Find the true length of a line whose projections are perpendicular to the ground line. The horizontal projection is 2 inches long, the bottom end being $\frac{1}{2}$ inch above the ground line. The vertical projection is 1 inch long, the top end being $\frac{1}{2}$ inch below the ground line.

NOTE. The idea for drawing the figures referred to in 4, 5, and 6 can be obtained from Figs. 120 and 121 in this textbook.

In the lower half of the plate, four more figures are to be drawn, also spaced as regularly as possible, so that the finished plate will be well balanced:

7. Draw the plan and elevation of a round bolt with a square head. The head is to be uppermost in the elevation. The bolt

is to be 2 inches long and $\frac{1}{2}$ inch in diameter. The head is to be $\frac{3}{4}$ inch square, $\frac{1}{4}$ inch thick, and have one face parallel to V.

8. Draw the plan and elevation of a round bolt having the same dimensions as in 7, but with a hexagonal head; the head to be uppermost in the elevation, and to be $\frac{3}{4}$ inch in width between faces $\frac{1}{4}$ inch thick, and to have one face parallel to V.

9. Draw the plan and elevation of a cylinder, perpendicular to H, 2 inches high and 2 inches in diameter, with a hole 1 inch in diameter passing vertically completely through it.

10. Draw the plan, elevation, and end view of a rectangular block 6 inches long, 2 inches wide, and 1 inch thick. One of the 2 inch by 6 inch sides is to be parallel to H. The right end is turned down to a cylindrical form 1 inch in length and 1 inch in diameter.

In all the work of this plate, construction lines should be fine dotted lines and should be inked in.

PLATE X

The figures on the reproduced Plate X on the opposite page give the outline of the work that is to be completed by the student. The dimensions given on this plate are to be used in working out the problem, but are not to appear on the finished plate. The first figure shown represents a rectangular block with a rectangular hole cut through from front to back. The other two figures represent the same block in different positions. In drawing these figures, the student must put in all construction lines in order to show how each view is obtained.

After completing the construction of the views as shown, the projection of four holes, $\frac{1}{2}$ inch in diameter each, are to be drawn. One hole passes through the center of each end, and one hole through the center of each side. All these small holes pass completely through to the large hole in the center of the block. Next, put two square projecting pieces on the front face of the block, on the center line, $\frac{1}{2}$ inch from each end. These projecting pieces are to be $\frac{1}{2}$ inch square and $\frac{1}{4}$ inch deep.

The projections of the four small holes and two projecting pieces are to be drawn in all views in the conventional manner, and the necessary construction lines for this work are to be left on the plate and inked in.

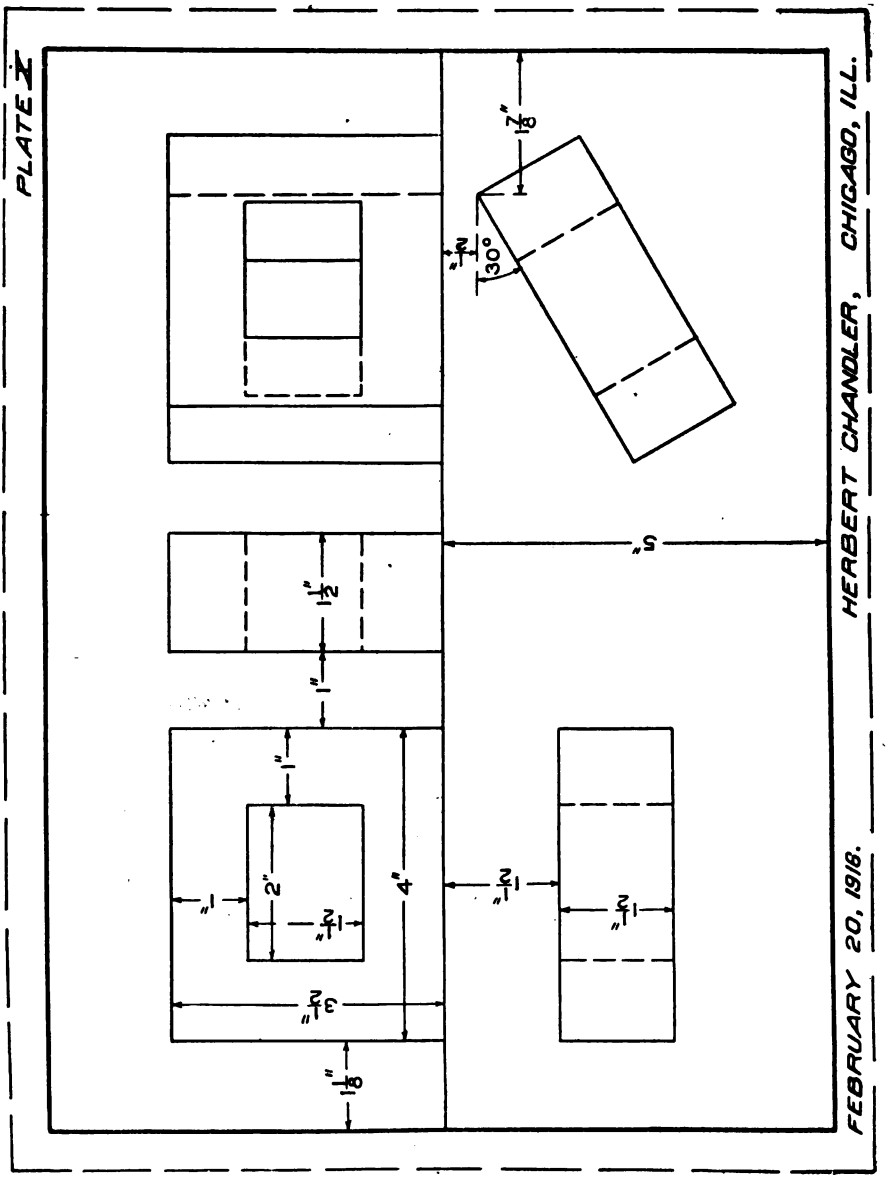


PLATE X
HERBERT CHANDLER, CHICAGO, ILL.
FEBRUARY 20, 1918.
5"
1 1/2"
1"
1"
2"
1"
4"
1 1/2"
1 1/2"
3 1/2"
1 1/8"
1 7/8"
30°
1 1/4"

PLATE XI

At the left of this plate draw the plan, front and side views of the monument shown in elevation on reproduced Plate XI on the opposite page. The total height of the monument is 6 inches. All four sides are alike except that the width of the base is 2 inches and the depth 1½ inches, and the width of the body of the monument is 1½ inches and the depth 1 inch. The height of the base is ½ inch, of body 3 inches, and the faces just above the base have a slope of 60 degrees with the horizontal. The width of the ridge at the extreme top of the monument is 1 inch.

The figures for the right side of the plate represent a pentagonal pyramid in three positions. The first position is the pyramid with the axis vertical. The height of the pyramid is 2½ inches, and the diameter of the circle circumscribed about the base 2½ inches. The center of the circle is 6 inches from the left margin and 2½ inches below the upper border line. Spaces between figures to be ½ inch.

In the second figure the pyramid has been revolved about the right-hand corner of the base as an axis, through an angle of 15 degrees. The axis of the pyramid, shown dot and dash, is therefore at 75 degrees. The method of obtaining 75 degrees and 15 degrees with the triangles was shown in Part I. From the way in which the pyramid has been revolved, all angles with V must remain the same as in the first position; hence the vertical projection will be the same shape and size as before. All points of the pyramid remain the same distance from V. The points on the plan are found on T-square lines through the corners of the first plan and directly above the points in elevation. In the third position the pyramid has been swung around, about a vertical line through the apex as axis, through 30 degrees. The angle with the horizontal plane remains the same; consequently the plan is the same size and shape as in the second position, but at a different angle. Heights of all points of the pyramid have not changed this time, and hence are projected across from the second elevation.

PLATE XII

DEVELOPMENTS

On this plate draw the developments of a truncated octagonal prism, and of a truncated pyramid having a square base. The

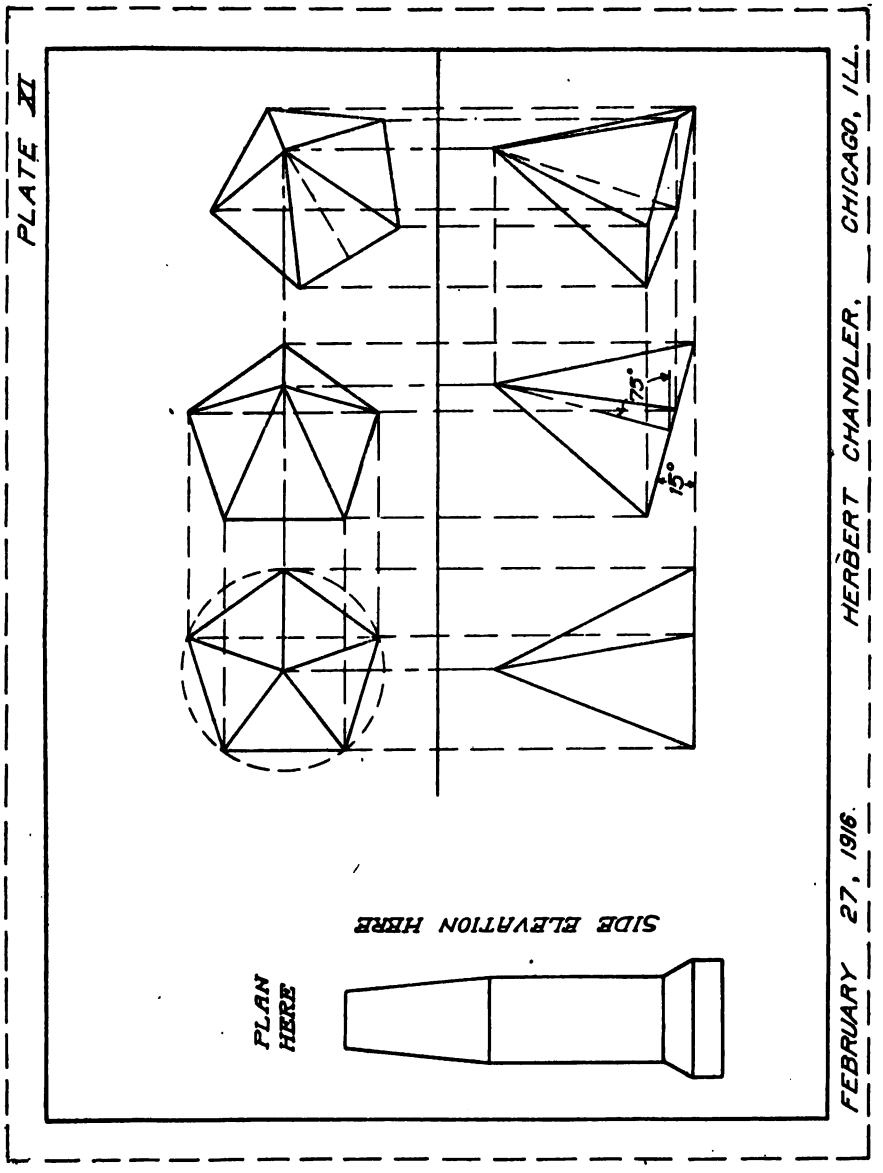


PLATE XI
HERBERT CHANDLER, CHICAGO, ILL.
FEBRUARY 27, 1916.
75°
15°
SIDE ELEVATION HERE
PLAN HERE

arrangement on the plate is left to the student; but it is suggested that the truncated prism and its development be placed at the left,

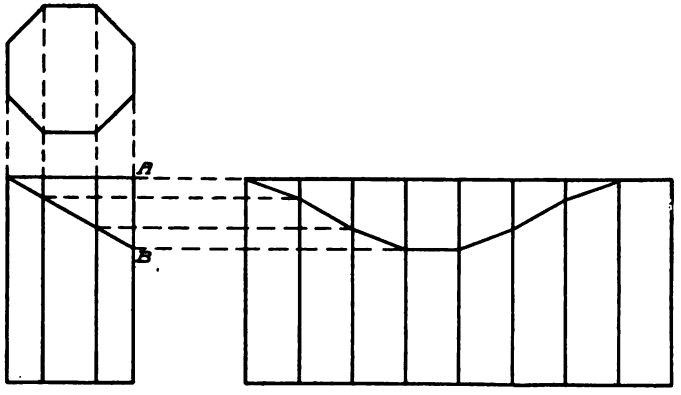


Fig. 203. Plan, Elevation, and Development of an Octagonal Prism

and that the development of the truncated pyramid be placed under the development of the prism; the truncated pyramid may be placed at the right.

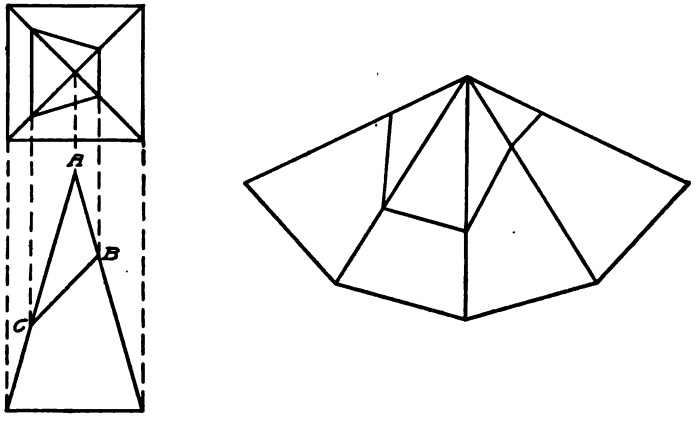


Fig. 204. Plan, Elevation, and Development of a Square Pyramid and Cutting Plane

The prism and its development are shown in Fig. 203. The prism is 3 inches high, and the base is inscribed in a circle $2\frac{1}{8}$ inches in diameter. The plane forming the truncated prism is passed as indicated, the distance AB being 1 inch. Ink a sufficient number of construction lines to show clearly the method of finding the development.

The pyramid and its development are shown in Fig. 204. Each side of the square base is 2 inches, and the altitude is $3\frac{1}{2}$ inches. The plane forming the truncated pyramid is passed in such a position that AB equals $1\frac{3}{8}$ inches, and AC equals $2\frac{1}{2}$ inches. In this figure the development may be drawn in any convenient position, but in the case of the prism it is better to draw the development as shown. Indicate clearly the construction by inking the construction lines.

PLATE XIII

ISOMETRIC AND OBLIQUE PROJECTION

In the upper left quarter of this plate draw the isometric projection of the block which is shown on reproduced Plate X, page 137, taking the dimensions from your finished Plate X. The idea for this problem can be obtained by referring to Fig. 158 in this textbook.

In the upper right quarter of this plate draw the isometric projections of the two round bolts described in 7 and 8 of Plate IX, taking dimensions from your finished Plate IX.

In the lower half of this plate draw, at 45 degrees, the oblique projections of the cylinder and the rectangular block, described in 9 and 10 of Plate IX, taking dimensions from your finished Plate IX. The idea for this can be obtained by referring to Figs. 175 and 179 in this textbook.

PLATE XIV

FREE-HAND LETTERING

On account of the importance of free-hand lettering, the student should practice it at every opportunity. For additional practice, and to show the improvement made since completing Part I, lay out Plate XIV in the same manner as Plate I, and letter all four rectangles. Use the same letters and words as in the lower right-hand rectangle of Plate I.

PLATE XV

LETTERING

First lay out Plate XV in the same manner as previous plates. After drawing the vertical center line, draw light pencil lines as

AMERICAN SCHOOL OF CORRESPONDENCE

(A Correspondence Institution)

CHICAGO, U.S.A.

COURSE

IN

Mechanical Engineering

DO NOT WRITE IN THIS SPACE

guide lines for the letters. The height of each line of letters is shown on the reproduced plate. The distance between the letters should be ½ inch in every case. The spacing of the letters is left to the student. He may facilitate his work by lettering the words on a separate piece of paper, and finding the center by measurement or by doubling the paper into two equal parts. The styles of letters shown on the reproduced plate should be used.

REVIEW QUESTIONS

ON THE SUBJECT OF

BUSINESS MANAGEMENT

1. Given your own choice, where would you engage in business on your own account?

2. What advantage have large cities over small towns for business purposes?

3. Describe exactly how you would secure new customers if you were in business on your own account.

4. Lay out copy for an advertisement suitable for a daily paper.

5. Make a list of the stock of fixtures and tools required for conducting your business.

6. What advantages has the *direct mail* method of advertising over other methods?

7. How would you compile a mailing list?

8. Write two good business-pulling letters, suitable for any time of the year.

9. Mention the books you would require in opening a new business.

10. What advantages does a printed contract form possess?

11. Mention all the items which must be included in your overhead charges.

12. The wholesale cost of a sink is $20. Your overhead expense is 15 per cent, and you want a profit of 10 per cent. How much will you sell the sink for?

13. What method would you adopt to hurry slow-paying customers?

14. Write in your own words a series of four letters which would help you collect your outstanding accounts.

REVIEW QUESTIONS

ON THE SUBJECT OF

ESTIMATING

1. What do you understand by the terms *lump-sum profit* and *percentage profit?*

2. What are the disadvantages to estimating by comparison?

3. How do you find the areas of circles, trapezoids, and spheres?

4. How much would you pay your help in your locality and what would you figure this at in your estimate?

5. Quote the average selling price for the following: $1\frac{1}{4}$-inch stop cock, $\frac{3}{4}$-inch ball cock and ball, 4-inch heavy cast-iron soil pipe, per foot, $\frac{1}{2}$-inch black and $\frac{1}{2}$-inch galvanized-iron pipe, and a pail of Portland cement.

6. Multiply 14×13, 20×17, 23×19, 24×23, 25×25.

7. Draw a plan, section, and elevation of a modern water closet.

8. Make a perspective drawing of a steam system to heat a garage and measure up the piping required.

9. How do you determine the size of pipe in any room heated by hot air?

10. How would you allow for overhead and profit on a $2000 job?

11. What would be the cost of supplying all the materials and labor for the plumbing installation shown in Fig. 12, the main stack is 4-inch, the wastes and vents 2-inch, and the drum traps 4-inch cast iron?

12. Mention all the essential features you would keep in mind in preparing your estimate.

REVIEW QUESTIONS

ON THE SUBJECT OF

CONTRACTS AND SPECIFICATIONS

---

1. Describe generally the *province* of the specification.
2. Describe generally the *characteristics* of the specification.
3. Describe generally the *limits* of the specification.
4. How do specifications affect and influence the cost of completed work?
5. Describe the position in the transaction of (a) the *Owner*, (b) the *Contractor*, (c) the *Specification Writer*.
6. Why should a Specification Writer make a special study of materials?
7. Describe the province of sand in mortar and how you would select a sand for use.
8. Give a list of trade catalogues you have collected.
9. State the points which the *formal contract* should cover.
10. What is the relation between the specification and the working drawings? When does one take precedence over the other?
11. Describe briefly the relations, first, between Owner and Architect; second, between Architect and Contractor; third, between Contractor and Owner.
12. Describe different ways in which payment may be arranged under contract.
13. How do municipal building laws affect the preparation of specifications?
14. What are the disadvantages of requiring the Contractor to warrant portions of the work?

GENERAL INDEX

GENERAL INDEX

In this Index the *Volume Number* appears in Roman numerals—thus I, II, III, IV, and the *Page Number* in Arabic numerals—thus: 1, 2, 3, 4, etc. For example: Volume IV, Page 327, is written, IV, 327.

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